CHAPTER 4

GASOLINE FUEL SYSTEMS

LEARNING OBJECTIVE: *Describe the different types of gasoline fuel systems, how the components function to provide fuel to the engine in proper quantities, and servicing of the gasoline fuel system.*

The purpose of the fuel system of the internal combustion engine is to provide a combustible mixture of fuel and air to the engine cylinders. The ratio of fuel to air must always be in correct proportions regardless of the speed and load of the engine.

GASOLINE FUEL SYSTEMS

LEARNING OBJECTIVE: *Identify the properties of gasoline and the components of a fuel system.*

The function of both the carburetor fuel system and the fuel injection system is to supply a combustible mixture of air and fuel to the engine. Major elements of the gasoline fuel supply system include the following: fuel tank and cap, fuel system emission controls, fuel lines, fuel pump, fuel filter, carburetor or fuel injection system, air cleaner, and exhaust system. Before discussing the components of a gasoline fuel system, you should understand the composition and properties of gasoline.

GASOLINE

Gasoline is a highly volatile flammable liquid hydrocarbon mixture used as a fuel for internal-combustion engines. Acomparatively economical fuel, gasoline is the primary fuel for automobiles worldwide. Chemicals, called additives, such as lead, detergents, and anti-oxidants, are mixedinto gasoline to improve its operating characteristics.

Antiknock additives are used to slow down the ignition and burning of gasoline. This action helps to prevent engine ping or knock (knocking sound produced by abnormal and excessively rapid combustion). Leaded gasoline has lead antiknock additives. The lead allows a higher engine compression ratio to be used without the fuel igniting prematurely. Leaded gasoline is designed to be. used in older vehicles that have little or no emission controls.

The fuel used today is unleaded gasoline. Unleaded gasoline, also called no-lead or lead-free, does NOT contain lead antiknock additives. Congress has passed laws requiring that all vehicles meet strict emission levels. As a result, manufacturers began using catalytic converters and unleaded fuel.

The properties a good gasoline should have are as follows:

- Proper volatility (how quickly the gasoline vaporizes)
- Resistance to spark knock, or detonation
- Oxidation inhibitors to prevent formationof gum in the fuel system
- Antirust agents to prevent rusting of metal parts in the fuel system
- Anti-icers to retard icing and fuel-line freezing
- Detergents to help keep the fuel system clean
- Dye for identification

PROPERTIES OF GASOLINE

For a gasoline fuel system to function properly, it is necessary that the fuel have the right qualities to burn evenly no matter what the demands of the engine are. To help you recognize the qualities required of gasoline used for fuel, let’s examine some of the properties of gasoline and their effects on the operation of the engine.

Volatility

The ease with which gasoline vaporizes is called VOLATILITY. A high volatility gasoline vaporizes very quickly. A low volatility gasoline vaporizes slowly. A good gasoline should have the right volatility for the climate in which the gasoline is used.

If the gasoline is too volatile, it will vaporize in the fuel system. The result will be a condition called VAPOR LOCK. Vapor lock is the formation of vapor in the fuel lines in a quantity sufficient to prevent the flow of gasoline through the system. Vapor lock causes the vehicle to stall from lack of fuel. In the summer and in hot climates, fuels with low volatility lessen the tendency toward vapor lock.

Antiknock Quality

In modern high compression gasoline engines, the air-fuel mixture tends to ignite spontaneously or to explode instead of burning rather slowly and uniformly. The result is a knock, a ping, or a detonation. For this reason, gasoline refiners have various ways to make gasoline that does not detonate easily.

Octane Rating

Agasoline that detonates easily is called low octane gasoline. A gasoline that resists detonation is called high octane gasoline.

The octane rating of a gasoline is a measurement of the ability of the fuel to resist knock or ping. A high octane rating indicates the fuel will NOT knock or ping easily. It should be used in a high compression or turbo-charged engine. A low octane gasoline is suitable for a low compression engine.

Octane numbers give the antiknock value of gasoline. A higher octane number (91) will resist ping better than a gasoline with a low octane number (83). Each manufacturer recommends an octane number for their engine.

AIR-FUEL RATIO

For proper combustion and engine performance, the right amounts of air and fuel must be mixed together. If too much fuel or too little fuel is used, engine power, fuel economy, and efficiency are reduced.

For a gasoline engine, the perfect air to fuel ratio is 15:1 (15 parts air to 1 part fuel by weight). Under constant engine conditions, this ratio can help assure that all fuel is burned during combustion. The fuel system must change the air-fuel ratio with the changes in engine-operating conditions.

Lean Air-Fuel Mixture

A lean air-fuel mixture contains a large amount of air. For example, 20:1 would be a very lean mixture. A slightly lean mixture is desirable for high gas mileage and low exhaust emissions. Extra air in the cylinder ensures that all the fuel will be burned; however, too lean of a mixture can cause poor engine performance (lack of power, missing, and even engine damage).

Rich Air-Fuel Mixture

A rich air-fuel mixture contains a little more fuel mixed with the air. For gasoline, 8:1(8 parts air to 1 part fuel) is a very rich mixture. A slightly rich mixture tends to increase power; however, it also increases fuel consumption and exhaust emissions. An overly rich mixture will reduce engine power, foul spark plugs, and cause incomplete burning (black smoke at engine exhaust).

GASOLINE COMBUSTION

For gasoline or any other fuel to burn properly, it must be mixed with the right amount of air. The mixture must then be compressed and ignited. The resulting combustion produces heat, expansion of the gases, and pressure.

Normal Combustion

Normal gasoline combustion occurs when the spark plug ignites the fuel and burning progresses smoothly through the fuel mixture. Maximum cylinder pressure should be produced after a few degrees of crank rotation after the piston passes TDC on the power stroke.

Normal combustion only takes about 3/1,000 of a second. This is much slower than an explosion. Dynamite explodes in about 1/50,000 of a second. Under some undesirable conditions, however, gasoline can be made to bum quickly, making part of the combustion like an explosion.

Abnormal Combustion

Abnormal combustion occurs when the flame does NOT spread evenly and smoothly through the combustion chamber. The lean air-fuel mixture, high-operating temperatures, low octane, and unleaded fuels used today make abnormal combustion a major problem that creates unfavorable conditions, such as the following:

• DETONATION results when part of the unburned fuel mixture explodes violently. This is the most severe engine damaging type of abnormal combustion. Engine knock is a symptom of detonation because pressure rises so quickly that parts of the engine vibrate. Detonation sounds like a hammer hitting the side of the engine. It can crack cylinder heads, blow head gaskets, burn pistons, and shatter spark plugs.

• PRE-IGNITION results when an overheated surface in the combustion chamber ignites the fuel mixture. Termed surface ignition, a hot spot (overheated bit or carbon, sharp edge, hot exhaust valve) causes the mixture to burn prematurely. A ping or mild knock is a light tapping noise that can be heard during pre-ignition. Pre-ignition is similar to detonation, but the action is reversed. Detonation begins after the start of normal combustion, and pre-ignition occurs before the start of normal combustion. Pre-ignition is common to modern vehicles. Some manufacturers say that some pre-ignition is normal when accelerating under a load.

• DIESELING, also called after-running or run-on, is a problem when the engine keeps running after the key is turned off. A knocking, coughing, or fluttering noise may be heard, as the fuel ignites and the crankshaft spins. When dieseling, the engine ignites the fuel from heat and pressure, somewhat like a diesel engine. With the key off, the engine runs without voltage to the spark plugs. The most common causes of dieseling are high idle speed, carbon deposits in the combustion chambers, low octane fuel, overheated engine, or spark plugs with too high of a heat range.

• SPARK KNOCK is another combustion problem caused by the spark plug firing too soon in relation to the position of the piston. The spark timing is advanced too far, causing combustion to slam into the upward moving piston. This causes maximum cylinder pressures to form before TDC, not after TDC as it should. Spark knock and pre-ignition both produce about the same symptoms—pinging under load. To find its cause, first check ignition timing. If ignition timing is correct, check other possible causes.

GASOLINE FUEL SYSTEM COMPONENTS

A gasoline fuel system (fig. 4-1) draws fuel from the tank and forces it into the fuel-metering device (carburetor, gasoline injectors), using either a mechanical (engine-driven) or electric fuel pump. The basic parts of a fuel supply system include the following:

- FUEL TANK (stores gasoline)
- FUEL PUMP (draws fuel from the tank and forces it to the fuel-metering device)
- FUEL FILTERS (removes contaminants in the fuel)

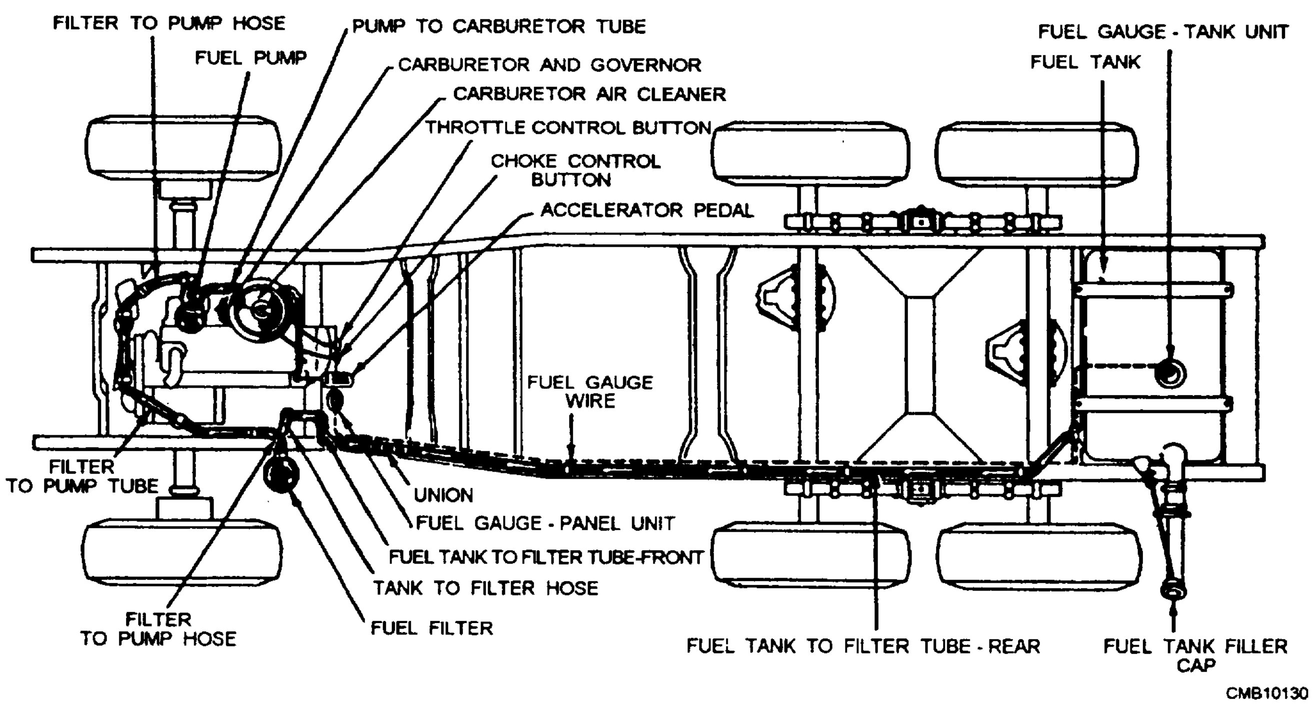

Figure 4-1.—Typical fuel system for a gasoline engine.

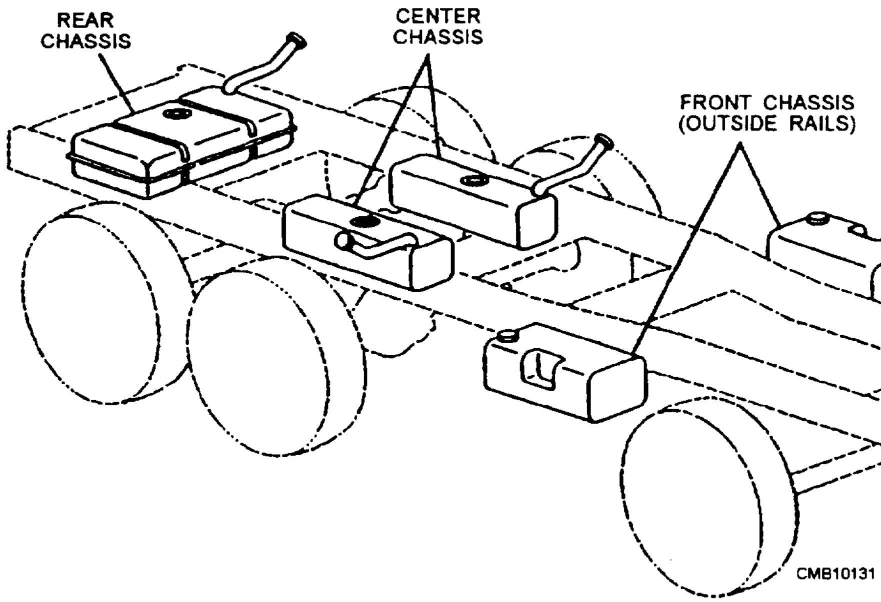

Figure 4-2.—Common fuel tank locations.

- FUEL LINES (carries fuel between the tank, the pump, and other parts)

Fuel Tank

An automotive fuel tank must safely hold an adequate supply of fuel for prolonged engine operation. The location of the fuel tank (fig. 4-2) should be in an area that is protected from flying debris, shielded from collision damage, and one that is not subject to bottoming. A fuel tank can be located just about anywhere in the vehicle that meets these requirements.

Figure 4-3 shows the general construction of a fuel tank used on automotive equipment. Fuel tanks are usually made of thin sheet metal or plastic. The main body of a metal tank is made by soldering or welding two formed pieces of sheet metal together. Other parts (filer neck, fuel tank cap, and baffles) are added to the form to complete the fuel tank assembly. A lead-tin alloy is normally plated to the sheet metal to prevent the tank from rusting.

The fuel tank filler neck is an extension on the tank for filling the tank with fuel. The filler cap fits on the end of the filler neck. The neck extends from the tank through the body of the vehicle. A flexible hose is normally used as part of the filler neck to allow for tank vibration without breakage.

In vehicles requiring unleaded fuel, a fuel neck restrictor is used inside the filler neck. This prevents the accidental use of leaded gasoline in an engine designed for unleaded. The restrictor is too small to accept the larger leaded fuel type pump nozzle.

WARNING

If the restrictor is removed and leaded fuel is used in a vehicle designed for unleaded fuel, the catalytic converter will be damaged. This action is a violation of federal law; therefore, NEVER remove the filler neck restrictor.

Modern fuel tank caps are sealed to prevent escape of fuel and fuel vapors (emissions) from the tank. The cap has pressure and vacuum valves that only open under abnormal conditions of high pressure or vacuum.

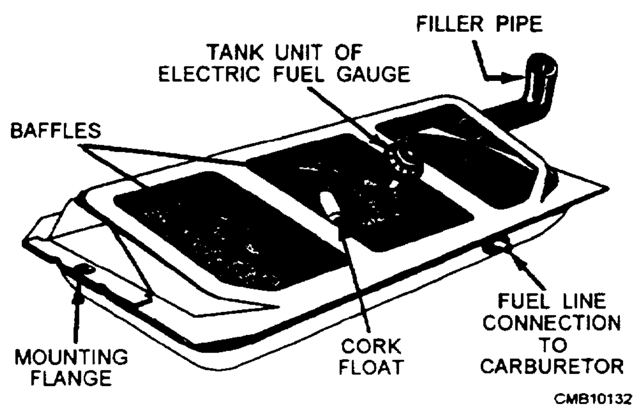

Figure 4-3.—Fuel tank with top cut away.

Fuel tank baffles are placed inside the tank to prevent the fuel from sloshing or splashing around in the tank. The baffles are metal plates that restrict fuel movement when the vehicle accelerates, decelerates, or turns comers.

Fuel tanks give little or no trouble, and generally require no servicing other than an occasional draining and cleaning.

WARNING

If a fuel tank is punctured or develops leaks, it should NOT be welded or repaired with or near an open flame until all traces of fuel and fuel vapors have been completely removed from the tank. Before attempting to make any repairs to a fuel tank, consult with the shop supervisor for specific instructions on all safety precautions to be observed.

Fuel Gauges

The fuel gauge is a signaling system that indicates the amount of fuel in the tank. Most fuel gauges are composed of two units—the gauge that is mounted on the instrument panel and the sending unit located on the tank

There are two types of gauges—magnetic and thermostatic. Each of these gauges has a sending unit and an instrument panel unit.

1. Magnetic Gauge (fig. 4-4). The sending unit in this fuel gauge contains a sliding contact. As the fuel level in the tank changes, the position of the contact changes on a rheostat winding, varying circuit resistance and resulting current flow. The unit on the instrument panel contains two magnetic coils (limiting coil and operating coil) and a permanent magnet that is attached to the gauge needle. When the fuel tank is empty, the limiting coil is stronger than the operating coil, thus the magnet is drawn toward it and the needle reads EMPTY on the gauge. As the tank is filled, the operating coil becomes stronger, attracting the magnet and moving the needle toward the FULL position.

2. Thermostatic Gauge (fig. 4-5). It has a sending unit similar to the magnetic system. The sending unit has a float and sliding contact that moves on a resistor. As the fuel level in the tank changes, the position of the contact changes on a rheostat winding, varying circuit resistance and resulting current flow. When the fuel is low in the tank, most of the resistance is in the circuit and very little current can flow. As the tank is filled, the float moves up and the sliding contact cuts most of the resistance out of the circuit. This action increases current flow and as the current flows through the heater coil in the gauge on the instrument panel, the current heats the thermostat. The thermostatic blade bends because of the heat. This moves the needle to the FULL mark. As the fuel level in the tank drops, resistance

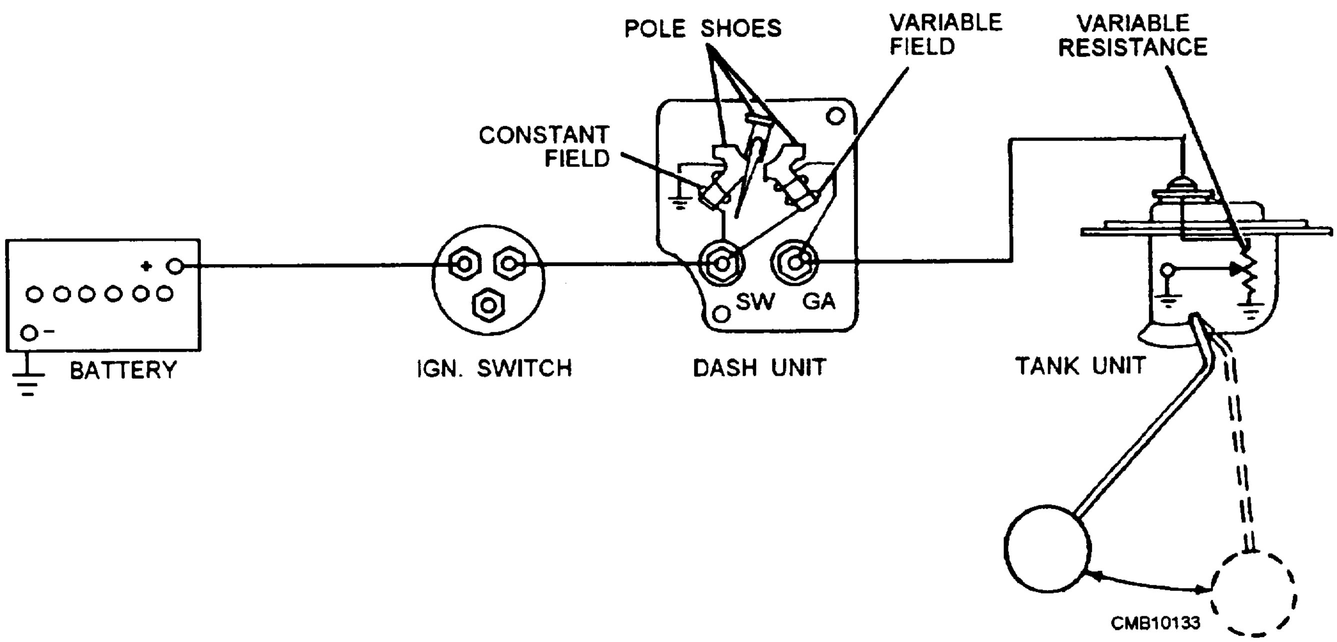

Figure 4-4.—Magnetic fuel gauge.

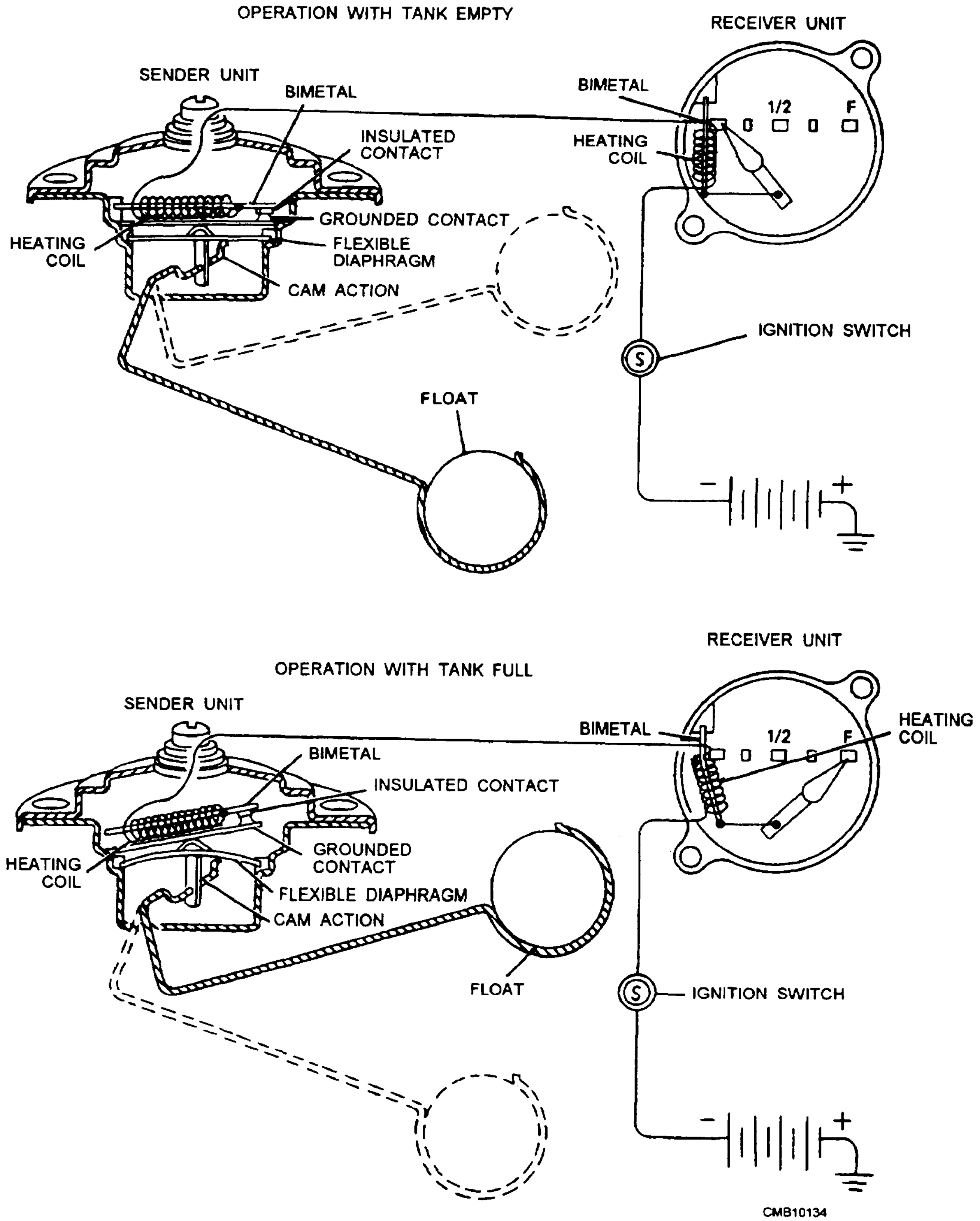

Figure 4-5.—Thermostatic fuel gauge: self-regulating.

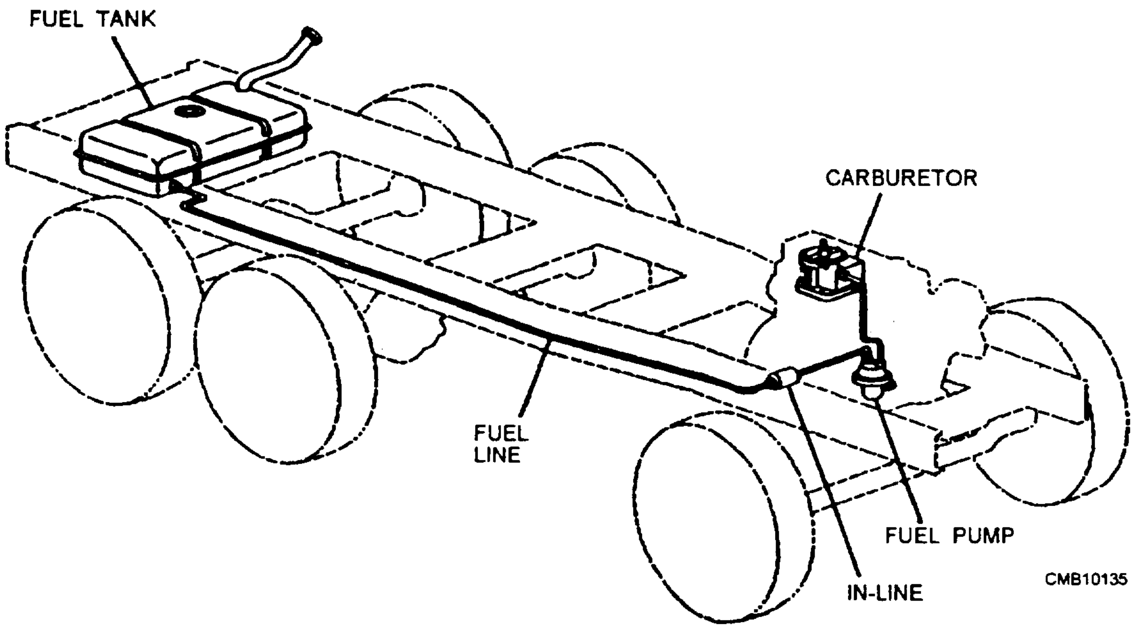

Figure 4-6.—Typical fuel filter locations.

increases, resulting in lower current flow through the heater coil, thus producing less heat to bend the thermostatic blade.

Fuel Filters

Fuel filters stop contaminants (rust, water, corrosion, and dirt) from entering the carburetor, throttle body, injectors, injections pumps, and any other parts that may be damaged by foreign matter. Fuel filters can be located in the following locations (fig. 4-6):

- In the fuel line before the carburetor or fuel injectors.
- Inside the fuel pump.
- In the fuel line right after the electric fuel pump.
- Under the fuel line fitting in the carburetor.
- A fuel strainer is also located in the fuel tank on the end of the pickup tube.

When in doubt about the location of the fuel filter, refer to the service manual.

Fuel filters operate by passing the fuel through a porous filtering medium (fig. 4-7). The openings in the porous material are very small, and, therefore, any particles in the fuel that are large enough to cause problems are blocked. In addition to the filtering medium, the filter, in some cases, also serves as a sediment bowl. The fuel, as it passes through the filter, spends enough time in the sediment bowl to allow large particles and water to settle out of it.

Several types of fuel filters are used today. They are the replaceable in-line, the replaceable in-line in the

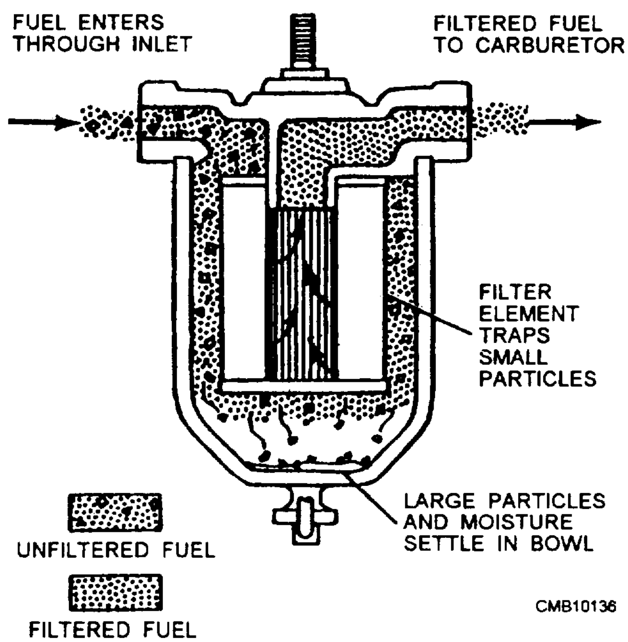

Figure 4-7.—Fuel filter operation.

carburetor, and the glass bowl (fig. 4-8). The most common configuration is the replaceable in-line filter. these are in-line filter elements that fit in the carburetor inlet or inside the fuel tank.

Fuel filter elements can be made from treated paper, ceramics, sintered bronze, or metal screen (fig. 4-9). However, there is one filter element that differs from the others. It consists of a stacked pile of laminated disks that are spaced 0.0003 inches apart. As the fuel passes between the disks, foreign matter is blocked out. These filters are replaced when the flow of fuel is restricted.

Fuel filter service involves periodic replacement or cleaning of system filters. It may also include locating clogged fuel filters that are upsetting fuel system operations. Paper elements must be replaced when clogged or after prolonged use. Sintered bronze fuel filters can usually be cleaned and reinstalled. A clogged fuel filter can restrict the flow of fuel to the carburetor or injectors. Engine Performance problems will show up at higher speeds.

Some fuel filters have a check valve that opens when the filter becomes clogged. This will allow fuel contaminants to flow into the system. When contaminants are found in the filters and system, the tank, the pump, and the lines should be flushed with clean fuel.

Always refer to the service manual for information concerning service intervals, cleaning, and replacement of all system filters.

Fuel Pump

The fuel pump delivers fuel from the tank to the engine under pressure. There are two basic types of fuel pumps—mechanical fuel pump and electrical fuel pump.

Mechanical fuel pumps are commonly used with carburetor type fuel systems. They are the oldest type of fuel pump, but they are still found on many vehicles. The mechanical fuel pump is mounted on the side of the engine block, using a gasket between the pump and the block to prevent oil leakage. Since the mechanical

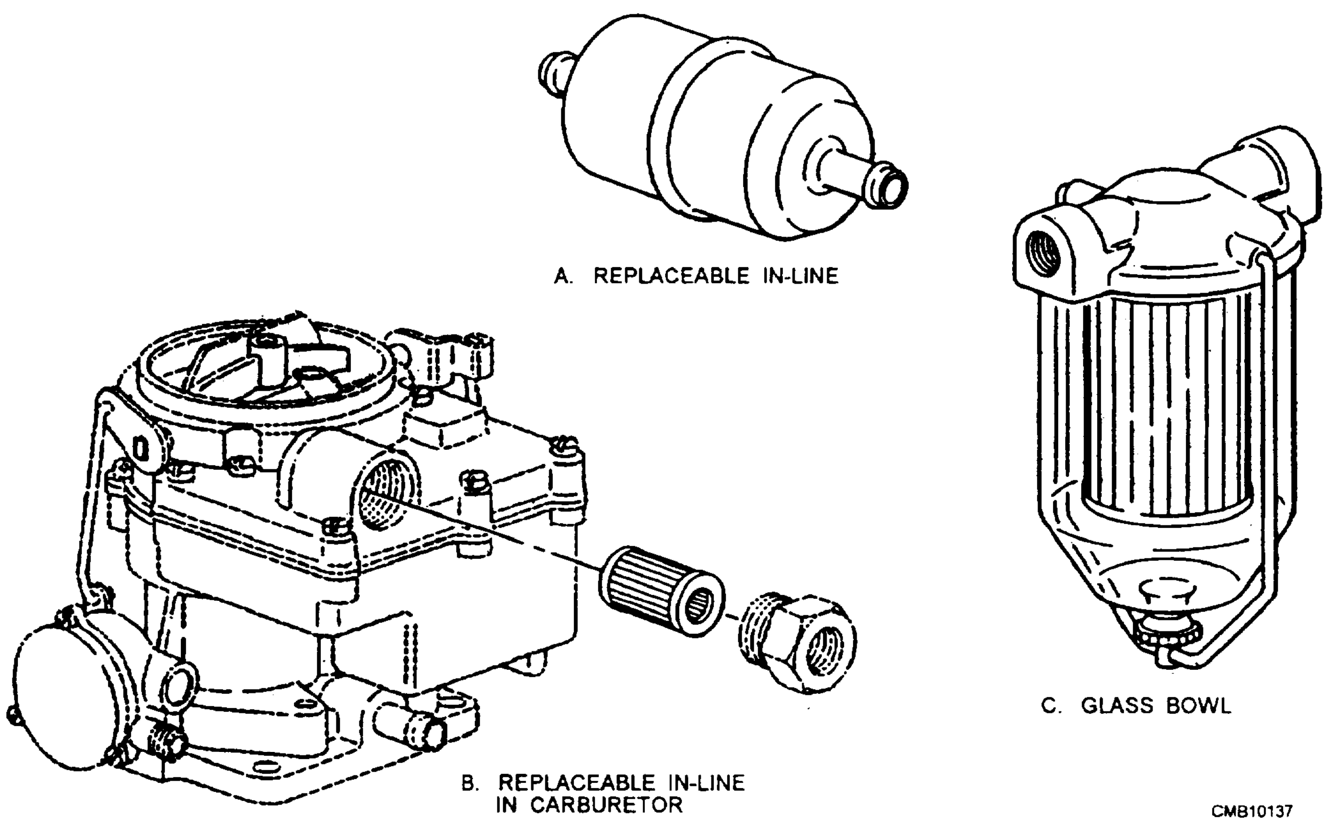

Figure 4-8.—Fuel filter configurations.

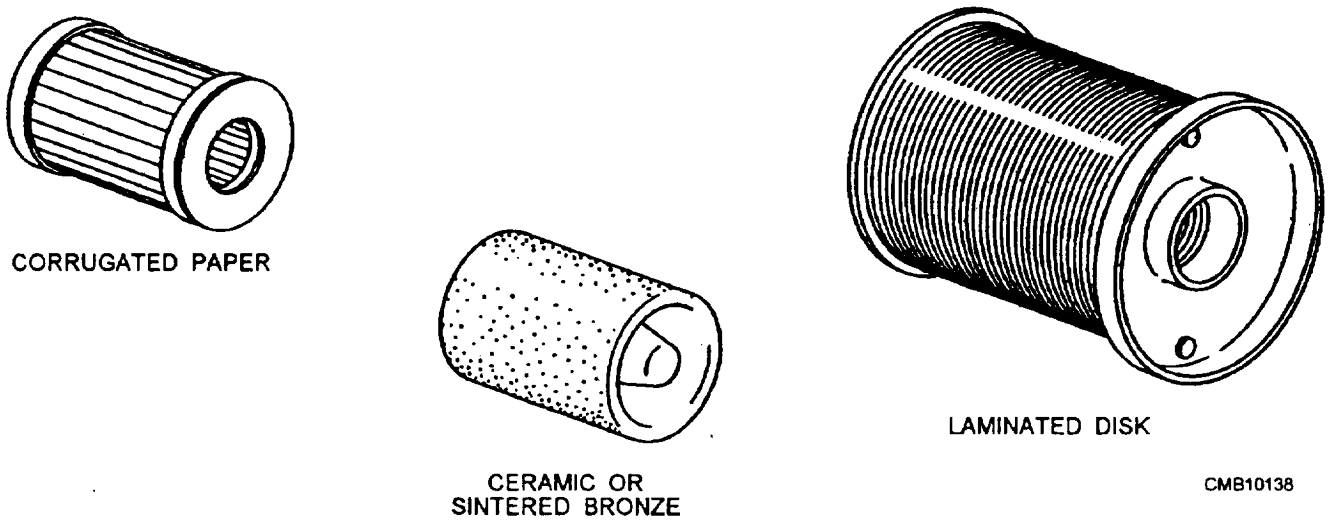

Figure 4-9.—Fuel filter elements.

pump uses a back-and-forth motion, it is a reciprocating pump. They are usually powered by an eccentric (egg-shaped lobe) on the engine camshaft.

The parts of a basic mechanical fuel pump are the rocker arm, the return spring, the diaphragm, the diaphragm spring, and the check valves.

- The ROCKER ARM, also called an actuating lever, is a metal arm hinged in the middle. A small pin passes through the arm and fuel pump body. The outer end of the arm rides on the camshaft eccentric and the inner end operates the diaphragm.

- The RETURN SPRING keeps the rocker arm pressed against the eccentric. Without a return spring, the rocker arm would make a loud clattering sound, as the eccentric lobe hits the rocker arm.

- The DIAPHRAGM is a synthetic rubber disc clamped between two halves of the pump body. The core of the diaphragm is usually cloth that adds strength and durability. A metal pull rod is mounted on the diaphragm to connect the diaphragm with the rocker arm.

- The DIAPHRAGM SPRING, when compressed, pushes on the diaphragm to produce fuel pressure and flow. This springs fits against the back of the diaphragm and against the pump body.

- The CHECK VALVES are used in a mechanical fuel pump to make the fuel flow through the pump. The check valves are reversed. This causes the fuel to enter one valve and exit through the other.

The basic operation of a mechanical fuel pump operation is as follows:

- INTAKE STROKE. The eccentric lobe pushes on the rocker arm. This action pulls the diaphragm down and compresses the diaphragm spring. Since the area in the pumping chamber increases, a vacuum pulls fuel through the inlet check valve.

- OUTPUT STROKE. The eccentric lobe rotates away from the pump rocker arm. This action releases the diaphragm. The diaphragm spring then pushes on the diaphragm and pressurizes the fuel in the pumping chamber. The amount of spring tension controls the fuel pressure. The fuel is then forced to flow out of the outlet check valve.

Mechanical fuel pumps are classified as positive and nonpositive diaphragm types. The POSITIVE type

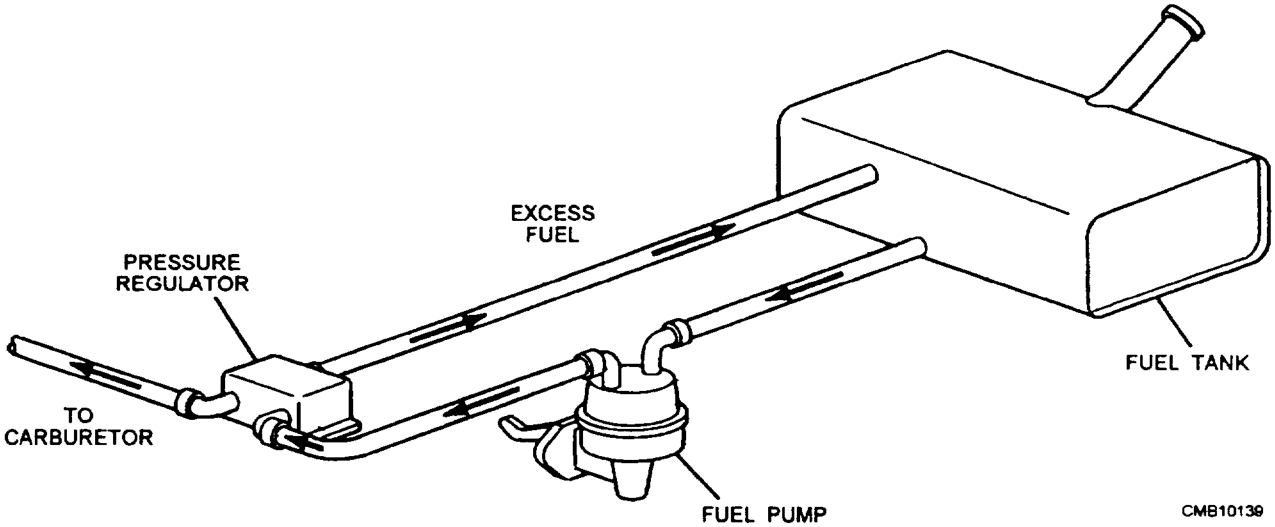

Figure 4-10.—Mechanical positive fuel pump installation.

(fig. 4-10) continues to pump fuel even when the carburetor bowl is filled; therefore, a method of bypassing the fuel back to the tank is required. The NONPOSITIVE type (fig. 4-11) is the one usually found in a gasoline engine. It delivers fuel to the carburetor only when it is needed for the requirements of the engine.

An electric fuel pump, like the mechanical pump, produces fuel pressure and flow for the fuel-metering section of a fuel system.

Electric fuel pumps are commonly used in gasoline fuel systems. They can be located inside the fuel tank as part of the fuel pickupsending unit. Also, it can be located in the fuel line between the tank and the engine.

The advantages an electric fuel pump has over the mechanical fuel pump are as follows:

- An electric fuel pump can produce almost instant fuel pressure. A mechanical pump slowly builds pressure as the engine is cranked for starting.
- Most electric fuel pumps are a rotary type. This produces a smoother flow of fuel (less pressure pulsations) than a reciprocating, mechanical pump.
- Since most electric pumps are located away from the engine, they help prevent vapor lock. An electric fuel pump pressurizes all of the fuel line near the engine heat. This helps avoid vapor lock because pressure makes it more difficult for bubbles to form in the fuel.

Electric rotary fuel pumps include the impeller, the roller vane, and the sliding vane types. They use a circular or spinning motion to produce pressure.

An impeller electric fuel pump is a centrifugal pump, normally located inside the fuel tank. This pump used a small motor to spin the impeller (fan blade). The impeller blades cause fuel to fly outward due to centrifugal force. This produces enough pressure to move the fuel through the fuel lines.

A roller vane electric fuel pump (fig. 4-12) is a positive displacement pump (each pump rotation moves a specific amount of fuel). This pump is located in the main fuel line. Small rollers and an offset mounted rotor disc produce fuel pressure in the pump. When the rotor disc and rollers spin, they pull fuel to one side. The fuel is then trapped and pushed to a smaller area on the opposite side of the pump housing. This action squeezes the fuel between the rollers and the fuel flows

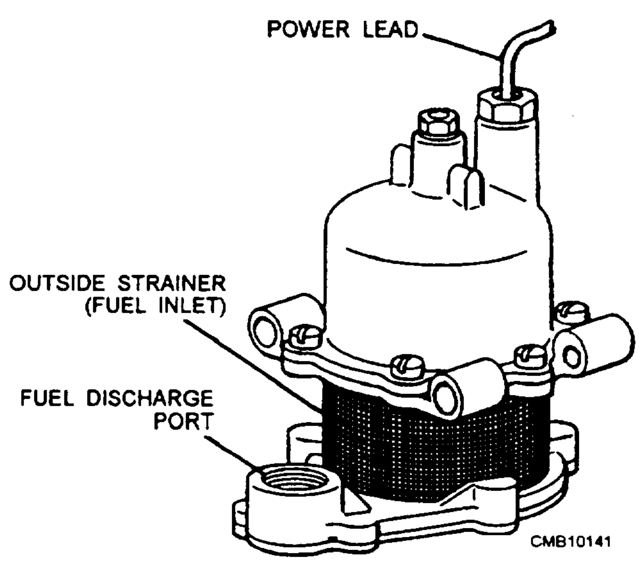

Figure 4-12.—Vane-type electric pump.

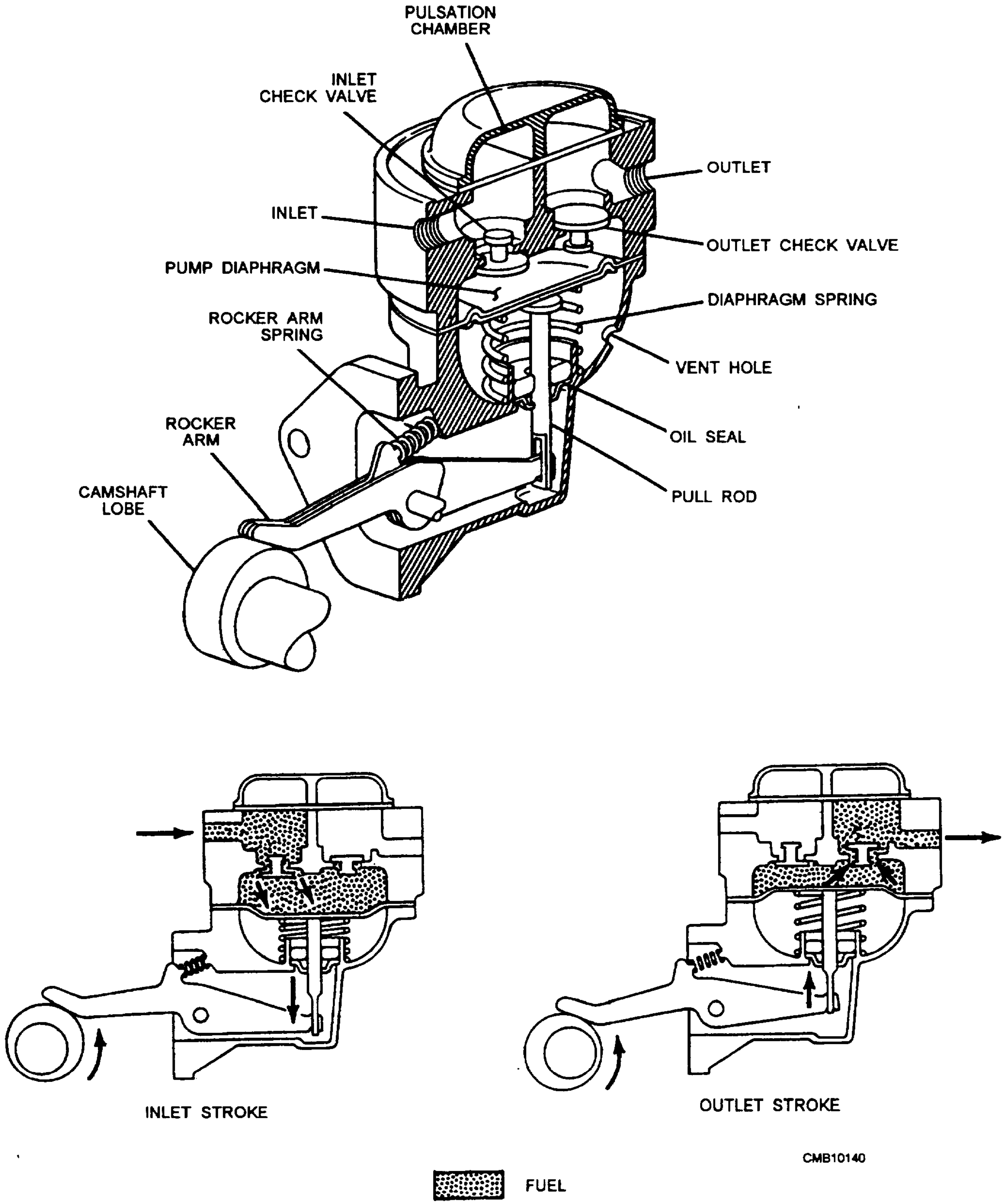

Figure 4-11.—Mechanical nonpositive fuel pump.

out under pressure. The sliding vane electric fuel pump is similar to the roller vane pump, except vanes (blades) are used instead of rollers.

Most rotary fuel pumps also have check valves and relief valves. The check valves keep the fuel from draining out of the fuel line when the pump is not in operation. A relief valve limits the maximum output pressure.

Another type of electric fuel pump is the reciprocating electric fuel pump. This pump has the same basic action as a mechanical fuel pump; however, it uses a solenoid instead of a rocker arm to produce a plunger action. The reciprocating pump uses either bellows (fig. 4-13) or a plunger. The solenoid turns on and off to force the bellows or plunger up and down. This action pushes fuel through the check valves and the fuel system.

Both mechanical and electric fuel pumps can fail after prolonged operation. Indications of fuel pump problems are as follows:

- LOW FUEL PUMP PRESSURE can be caused by a weak diaphragm spring, ruptured diaphragm, leaking check valves, or physical wear of moving parts. Low fuel pressure can make the engine starve for fuel at higher engine speeds.

- HIGH FUEL PUMP PRESSURE, more frequent with electric fuel pumps, indicates an inoperative pressure relief valve. If the valve fails to open, both pressure and volume can be above normal. High fuel pump pressure can produce a rich fuel mixture or even flood the engine.

- MECHANICAL FUEL PUMP NOISE (clacking sound from inside the pump) is commonly caused by weak or broken rocker arm return spring or by wear of the rocker arm pin or arm itself. This noise can be easily confused with valve or tappet clatter. To verify mechanical pump noise, use a stethoscope.

- FUEL PUMP LEAKS are caused by physical damage to the pump body or deterioration of the diaphragm and gaskets. Most mechanical fuel pumps have a small vent hole in the pump body. When the diaphragm is ruptured, fuel will leak out of this hole.

Fuel pump testing commonly involves measuring pump pressure and volume. Since exact procedures vary depending on the type of fuel system, refer to the manufacturer's manual for exact testing methods. Sometimes, fuel pump vacuum is measured as another means of determining pump and line condition. Always remember that there are several other problems that can produce symptoms similar to those caused by a fuel

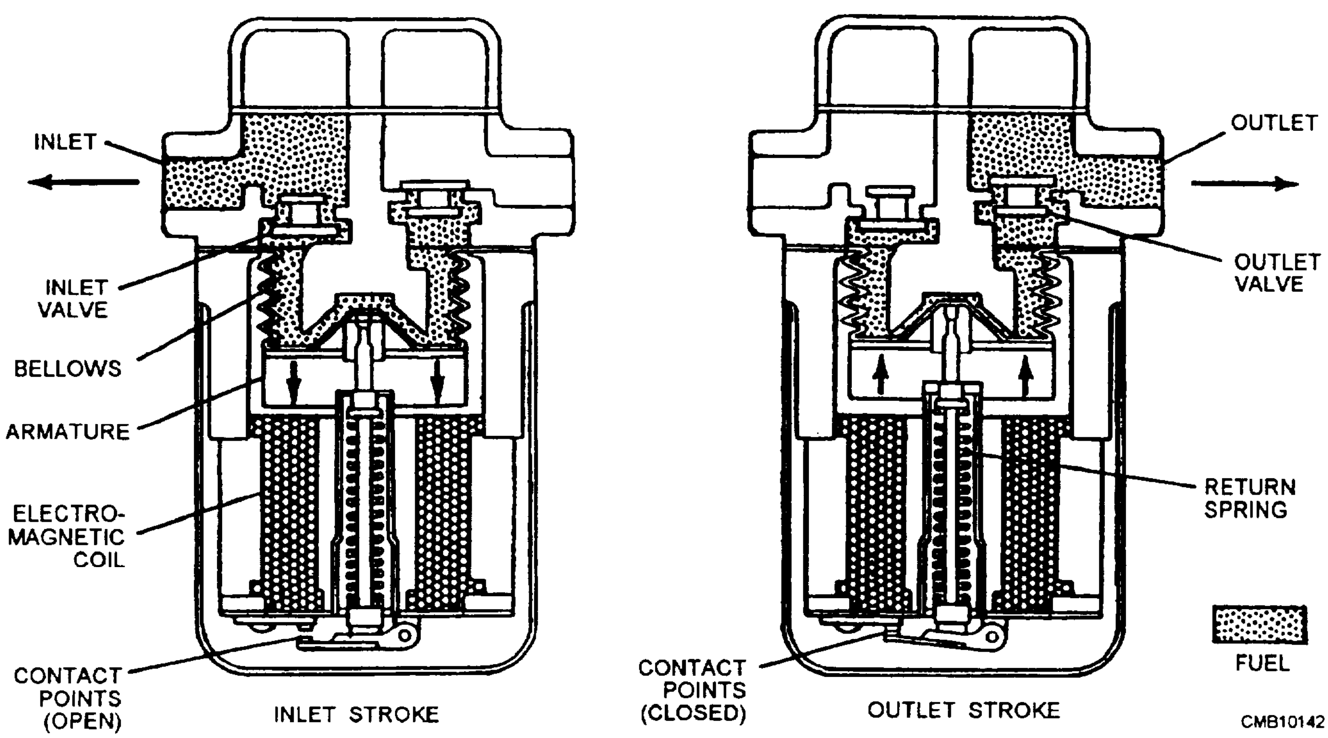

Figure 4-13.—Bellows-type electric fuel pump.

pump. Before testing a fuel pump, check for the following:

- Restricted fuel filters
- Smashed or kinked fuel line or hoses
- Air leak into the vacuum side of pump or line
- Carburetor or injection system problems
- Ignition system problems
- Low engine compression

To measure fuel pump pressure, connect a pressure gauge to the output line of the fuel pump. Start and idle the engine at the rpm specified by the manufacturer with a mechanical fuel pump. With an electric fuel pump, you may only need to activate the pump motor. Compare your pressure reading to the manufacturer's specifications. Fuel pressure for a carburetor type system is approximately 4 to 6 psi. A gasoline injection system will usually have a high-pressure output, varying from 15 to 40 psi. If fuel pump pressure is NOT within specifications. check the pump volume, the lines, and the filters before replacing the pump.

Fuel pump volume is the amount of fuel the pump can deliver in a specific amount of time. It is measured by allowing the fuel to pour into a graduated (marked) container for a certain amount of time (normally 30 seconds). Route an output line from the fuel pump to a measuring container. For safety, a valve or clip should be installed to control fuel flow into the container. With the engine idling at a set speed, allow the fuel to pour into the container for the prescribed amount of time. Close off the clip or the valve and compare volume output to the specifications. Output should be a minimum of 1 pint in 30 seconds for carburetor systems. Fuel injection systems have a slightly higher output from the supply pump. Always refer to the service manual specifications for the particular fuel pump and vehicle. If the fuel pump fails both pressure and volume test, then check the fuel pump vacuum.

A vacuum test will eliminate possible problems in the fuel lines, the hoses, the filters, and the pickup screen in the tank. For example, a clogged fuel pickup screen could make the fuel pump fail the volume test. To measure vacuum, connect a vacuum gauge to the inlet side of the pump, leaving the fuel hose from the volume test in the graduated container. Open the control valve on the hose and start the engine and allow it to run on the fuel in the carburetor, or connect voltage, to an electric pump. Compare your reading with the manufacturer's specifications. Normally, fuel pump vacuum should be about 7 to 10 in/hg. A good reading indicates a good fuel pump. If the pump failed the pressure or volume test but passed the vacuum test, the fuel supply lines and filter may be at fault.

Fuel Lines and Hoses

Fuel lines and hoses carry fuel from the tank to the engine. The main fuel line allows the fuel pump to draw fuel out of the tank. The fuel is pulled through this line to the pump and then to the carburetor, or metering section of the injection system.

Fuel lines are normally made of double wall steel tubing. For fire safety, a fuel line must be able to withstand the constant and severe vibration produced by the engine and road surface. Lines are placed away from exhaust pipes, mufflers, and manifolds, so that excessive heat will not cause vapor lock. They are attached to the frame, the engine, and other units, so the effects of vibration will be minimized.

Fuel hoses, made of synthetic rubber, are used where severe movement occurs between parts. A flexible hose can absorb movement without breaking. Hose clamps are required to secure fuel hoses to the fuel lines or to metal fittings.

Faulty fuel lines and hoses are a common source of fuel leaks. Fuel hoses can become hard and brittle after being exposed to the engine heat and the elements. Engine oil can soften and swell them. Always inspect hoses closely and replace any in poor condition. Metal fuel lines rarely cause problems; however, they should be replaced if they become smashed, kinked, rusted, or leaking. Remember these rules when working with fuel lines and hoses:

- Place a rag around the fuel line fitting during removal. This action will keep fuel from spraying on you or on a hot engine. Use a flare nut or tubing wrench on fuel line fittings.

- Use only approved double wall steel tubing for fuel lines. NEVER use copper or plastic tubing.

- Make smooth bends when forming a new fuel line. Use a bending spring or bending tool.

- Form double lap flares on the ends of fuel lines. A single lap flare is NOT approved for fuel lines.

- Reinstall fuel line hold-down clamps and brackets. If not properly supported, the fuel line can vibrate and fail.

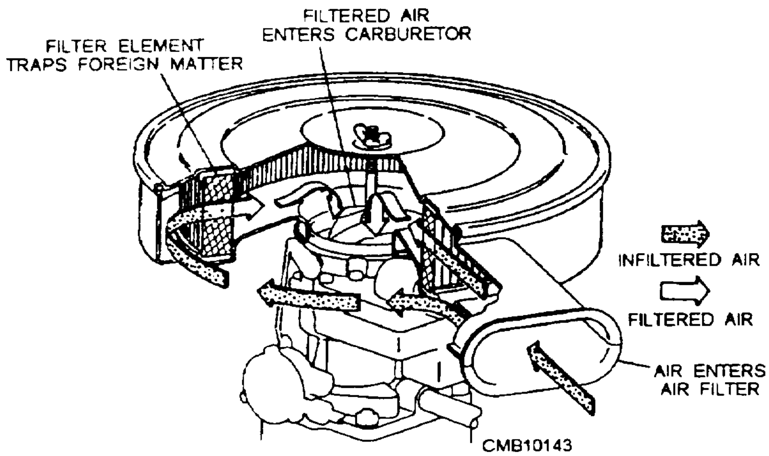

Figure 4-14.—Air cleaner.

- Route all fuel lines and hoses away from hot or moving parts. Double-check the clearance after installation.

- Only use approved synthetic rubber hoses in a fuel system. Vacuum hose is NOT to be used as fuel hose.

- Make sure fuel hoses completely cover its fitting or line before installing clamps. Pressure in the fuel system could force the hose off if not installed properly.

- Double-check all fitting for leaks. Start the engine and inspect the connections closely.

NOTE

Most fuel injection systems have very high fuel pressure. Follow recommended procedures for bleeding or releasing pressure before disconnecting a fuel line or fitting. This action will prevent fuel spray from possibly causing injury or a fire.

AIR CLEANER

The fuel system mixes air and fuel to produce a combustible mixture. A large volume of air passes through the carburetor or fuel injection system and engine, as much as 100,000 cubic feet of air every 1,000 miles. Air always contains a lot of floating dust and grit. The dust and grit could cause serious damage if they entered the engine. To prevent this, mount an air cleaner (fig. 4-14) at the air entrance of the carburetor or fuel injection system. The two types of cleaners currently used are the wet and dry types.

The wet-type. or oil bath, air cleaner consists of the main body, the filter element that is made of woven copper gauze, and the cover (fig. 4-15). Operation is as follows:

- Incoming air enters between the cover and the main body. The air is pulled down to the bottom of the main body where it must make a 180-degree turn, as it passes over the oil reservoir.

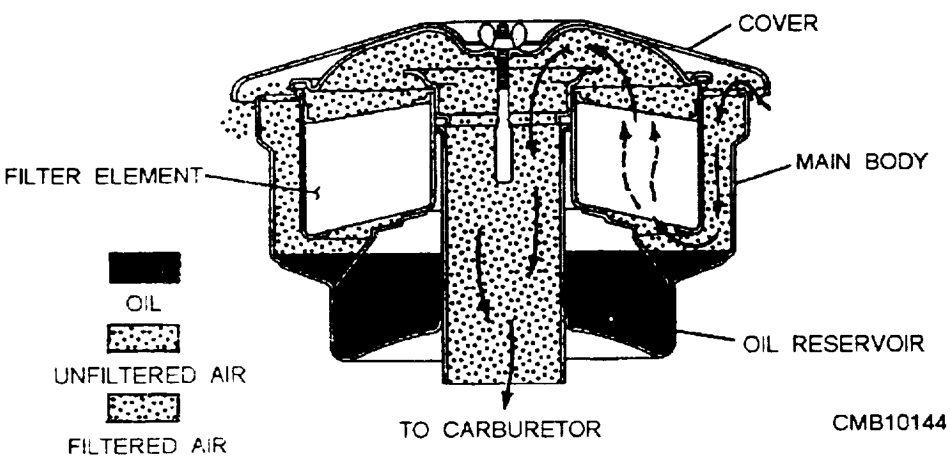

Figure 4-15.—Wet-type air filter.

- As the air passes over the oil reservoir, most of the particles will not be able to make the turn, and they will hit the oil and be trapped.

- As the air continues upward and passes through the filter element, the smaller particles that bypassed the oil will be trapped.

- The air keeps the element soaked with oil by creating a fine spray, as it passes the reservoir.

- The air then makes another 180-degree turn and enters the carburetor.

The dry-type air cleaner passes the incoming air through a filtering medium before it enters the engine. The air filter contains a ring of filter material (fine-mesh metal threads or ribbons, pleated paper, cellulose fiber, or polyurethane), as shown in figure 4-16. These types of filter materials provide a fine maze that traps most of the airborne particles.

The air cleaner also muffles the noise of the intake air through the carburetor or fuel injection system, manifold, and valve ports. This noise would be very noticeable if it were not for the air cleaner. In addition the air cleaner acts as a flame arrester in case the engine backfires through the intake manifold. The air cleaner prevents the flame from escaping and igniting gasoline fumes outside the engine.

Q1. *What fuel additive is used to prevent engine ping or knock?*

Q2. *What is the measurement* of *the ability of gasoline* to *resist knock or ping?*

Q3. *What device is used to prevent the accidental use of leaded fuel in a vehicle designedfor unleaded fuel?*

Q4. *What are the two types of air cleaners currently being used?*

PRINCIPLES OF CARBURETION

LEARNING OBJECTIVE: *Describe the operating systems and principles of a simple carburetor and a computerized controlled carburetor. Identify the different carburetor accessories and their functions. Identify and describe possible carburetor troubles and quick system checks.*

The principles of carburetion are presented so you may better understand the inner workings of a carburetor and how the other components of the fuel system function to provide a combustible mixture or air and fuel to the engine cylinders.

Air is composed of various gases, mostly nitrogen and oxygen (78 percent nitrogen and 21 percent oxygen by volume). These gases are, in turn, made up of tiny particles called molecules. All substances, whether solid, liquid, or gas, are made up of molecules. In solids, such as ice or iron, the particles are held closely together so that they seem to have no motion. In liquids, the molecules are not held together tightly, so they can move freely with respect to each other. In gases, there is still less tendency for the molecules to bond; therefore, the molecules can move quite freely. The molecules of gas are attracted to the earth by gravity or by their weight. It is the combined weight of the countless molecules in the air that make up atmospheric pressure.

Evaporation is the changing of a liquid to a vapor. The molecules of the liquid not being closely tied together are constantly moving among themselves. Any molecule that moves upward with sufficient speed will jump out of the liquid and into the air. This process will cause the liquid to evaporate over a period of time. The rate of evaporation is dependent on the following:

- TEMPERATURE. The rate of movement of the molecules increase with temperature. Because of this,

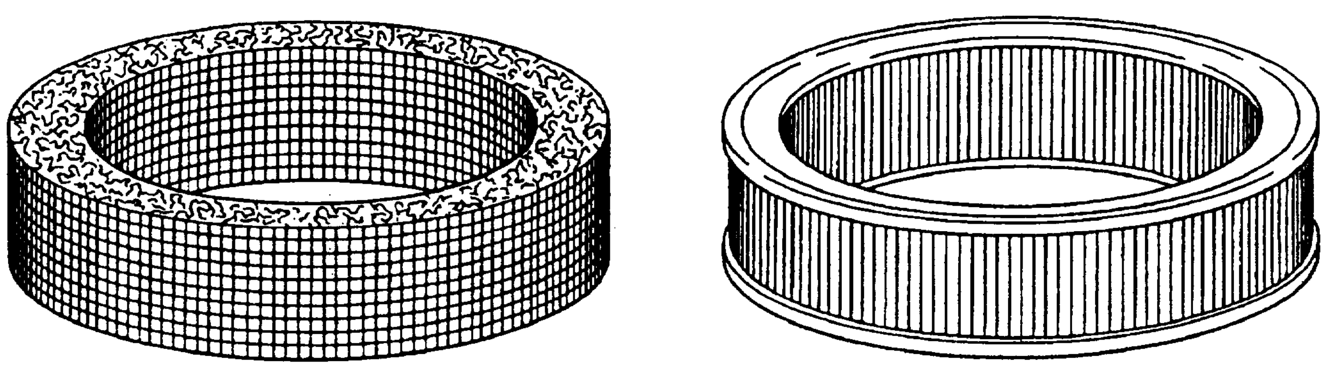

Figure 4-16.—Dry-type air filter.

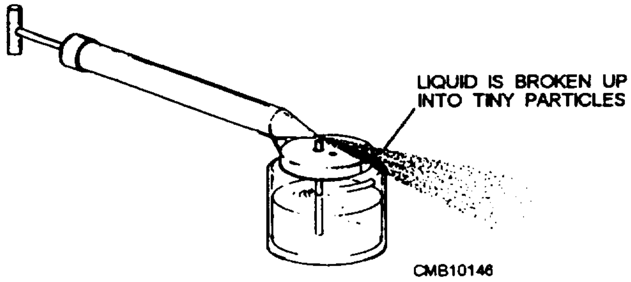

Figure 1-17.—Example of atomization.

the amount of molecules leaving the liquid for a given time will increase, as the temperature increases.

- ATMOSPHERIC PRESSURE. As atmospheric pressure increases, the amount of air molecules present over the liquid also increases. The increased presence of air molecules will slow the rate of evaporation. This is because the molecules of liquid will have more air molecules to collide with. In many cases, they will fall back into the liquid after the collision

- CLOSED CHAMBER. As evaporation takes place in a closed container, the space above the liquid will reach a point of saturation. When this happens, every molecule of liquid that enters the air will cause another airborne molecule of liquid to fall back.

- VOLATILITY. The term volatility refers to how fast a liquid vaporizes. Some liquid vaporizes easily at room temperature. Alcohol, for instance, vaporizes more easily than water. A highly volatile liquid is one that is considered to evaporate easily.

- ATOMIZATION (fig. 4-17). Atomization is the process of breaking up a liquid into tiny particles or droplets. When a liquid is atomized, the droplets are all exposed individually to the air. For this reason, atomization greatly increases evaporation by increasing the exposed surface area of the liquid.

The venturi effect (fig. 4-18) is used by the carburetor to mix air with the gasoline. The basic carburetor has an hourglass-shaped tube called a throat. The most constricted part of the throat is called the venturi. A tube, called the discharge nozzle, is positioned in the venturi. The discharge nozzle is connected to a reservoir of gasoline called the float bowl. The negative pressure that exists in the combustion chamber is due to the downward intake stroke of the piston, causing atmospheric pressure to create an air flow through the throat. This air flow must increase temporarily in speed, as it passes through the venturi due to its deceased size. The increased speed of air flow results in a corresponding decrease in pressure within the venturi and at the end of the discharge nozzle. This action permits the atmospheric pressure on the surface of the gasoline in the float bowl to force the gasoline out through the discharge nozzle. This gasoline then sprays and atomizes in the passing air flow to form the air-fuel mixture.

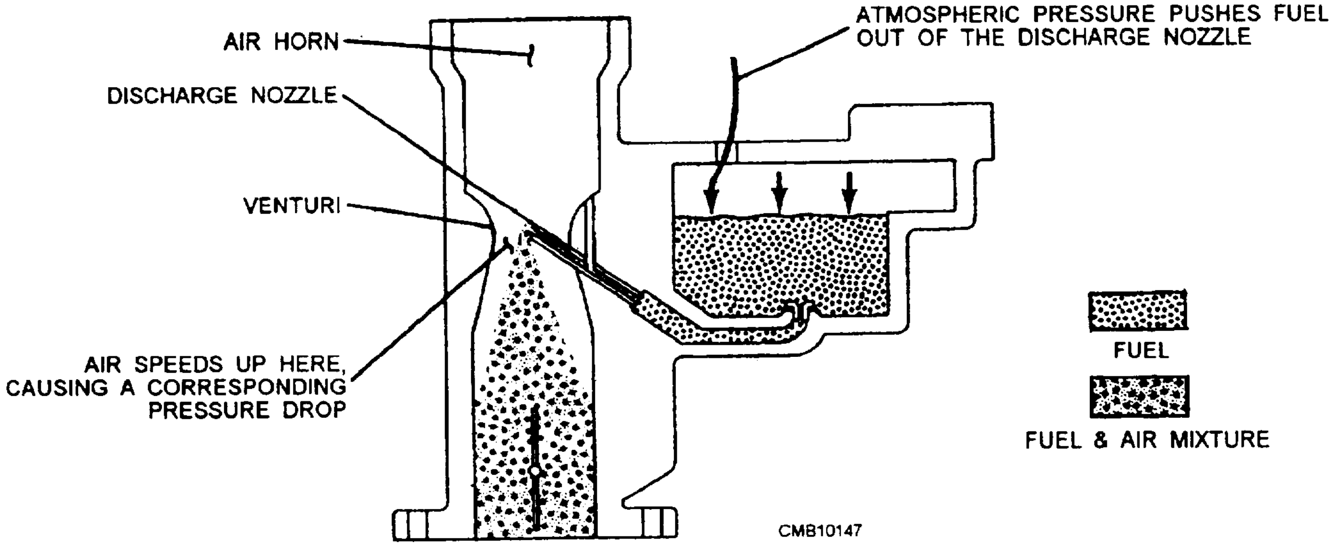

Figure 4-18.—Venturi effect.

CARBURETOR

A carburetor is basically a device for mixing air and fuel in the correct amounts for efficient combustion. The carburetor bolts to the engine intake manifold. The air cleaner fits over the top of the carburetor to trap dust and dirt. The basic carburetor consists of the following parts:

- CARBURETOR BODY. The carburetor body is a cast metal housing for the carburetor components. Usually the main body houses the fuel bowl, main jets, air bleeds, power valve, pump checks, diaphragm type accelerator pump, venturis, circuit passages, and float mechanism. The body is flanged on the bottom to allow the carburetor to be bolted to the intake manifold.

- AIR HORN. The air horn is also called the throat or barrel. It routes outside air into the engine intake manifold. It contains the throttle valve, the venturi, and the outlet end of the main discharge tube. The parts which often fasten to the air horn body are as follows: the choke, the hot idle compensator, the fast idle linkage rod, the choke vacuum break, and sometimes the float and pump mechanisms.

- THROTTLE VALVE (fig. 4-19). This disc-shaped valve controls air flow through the air horn. When closed, it restricts the flow of air and fuel into the engine, and when opened, air flow, fuel flow, andengine power increase.

- VENTURI. The venturi produces sufficient suction to pull fuel out of the main discharge tube.

- MAIN DISCHARGE TUBE. The main discharge tube is also called the main fuel nozzle. It uses venturi vacuum to feed fuel into the air horn and engine. It is a passage that connects the fuel bowl to the center of the venturi.

- FUEL BOWL. The fuel bowl holds a supply of fuel that is NOT under fuel pump pressure.

Carburetor size is stated in CFM (cubic feet of air per minute). This is the amount of air that can flow through the carburetor at wide, open throttle. CPM is an indication of the maximum air flow capacity. Usually, small CPM carburetors are more fuel-efficient than larger carburetors. Air velocity, fuel mixing, and atomization are better with small throttle bores. A larger CPM rating is desirable for high engine power output.

A carburetor system or circuit is a network of passages and related parts that help control the air-fuel ratio under specific engine-operating conditions. The seven basic carburetor systems are the following:

1. FLOAT SYSTEM
2. IDLE SYSTEM
3. OFF IDLE SYSTEM
4. ACCELERATION SYSTEM
5. HIGH-SPEED SYSTEM
6. FULL-POWER SYSTEM
7. CHORE SYSTEM

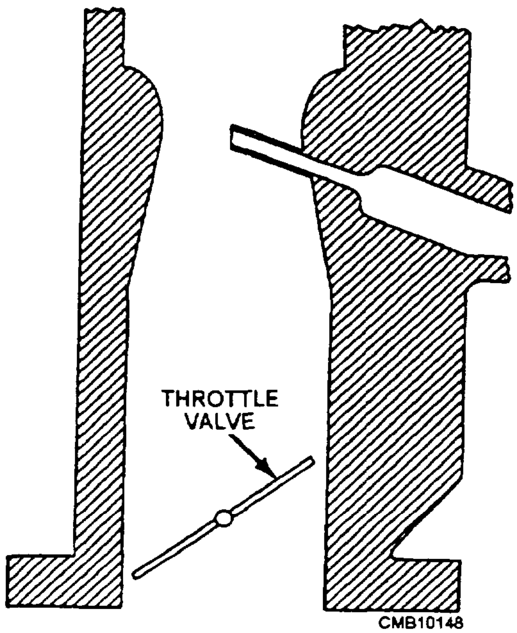

Figure 4-19.—Simple carburetor with throttle valve.

Understanding each of these systems is important. It will help you when diagnosing and repairing carburetor problems.

Float System

The float system (fig. 4-20) maintains a steady working supply of gasoline at a constant level in the carburetor. This action is critical to the proper operation of the carburetor. Since the carburetor uses differences in pressure to force fuel into the air horn, the fuel bowl must be kept at atmospheric pressure. The float system keeps the fuel pump from forcing too much gasoline into the carburetor bowl. An excessively high float level will cause fuel to flow too freely from the discharge tube, causing an overly rich mixture, whereas an excessively low float level will cause an overly lean mixture. The basic parts of the float system are the fuel bowl, the float, the needle valve, the needle seat, the bowl vent, and the hinge assembly. Study the relationship of each part as follows:

- The CARBURETOR FLOAT rides on top of the fuel in the fuel bowl to open and close the needle valve. It is normally made of thin brass or plastic. One end of the float is hinged to the side of the carburetor body and the other end is free to swing up and down.

- The NEEDLE VALVE regulates the amount of fuel passing through the fuel inlet and the needle seat. The needle valve is usually made of brass. Sometimes the end of the valve will have a soft viton (synthetic rubber) tip. The soft tip seals better than a metal tip, especially if dirt gets caught in the needle seat.

- The NEEDLE SEAT works with the needle valve to control fuel flow into the bowl. It is a brass fitting that threads into the carburetor body.

- The BOWL VENT prevents pressure or vacuum buildup in the carburetor fuel bowl. Without venting, pressure could form in the bowl, as the fuel pump fills the carburetor. This could also cause vacuum to form in the bowl, as fuel is drawn out of the carburetor and into the engine. On vehicles equipped with an evaporation control type emission system, the fuel bowl is vented into a hose going to a charcoal canister instead of the outside. The canister stores toxic fuel vapors and prevents them from entering the atmosphere.

Basic float system operation is as follows:

- When engine speed or load increases, fuel is rapidly pulled out of the fuel bowl and into the venturi. This action causes the fuel to drop in the bowl. The needle valve also drops away from its seat. The fuel pump can then force more fuel into the bowl.

- As the fuel level in the bowl rises, the float pushes the needle valve against its seat. When the fuel level is high enough, the float closes the opening between the needle valve and the seat by the rising float, as the fuel reaches the desired level in the fuel bowl.

With the engine running, the needle valve usually lets some fuel leak into the bowl. As a result, the float system maintains a stable quantity of fuel in the bowl. This is very important because the fuel level in the bowl can affect the air-fuel ratio.

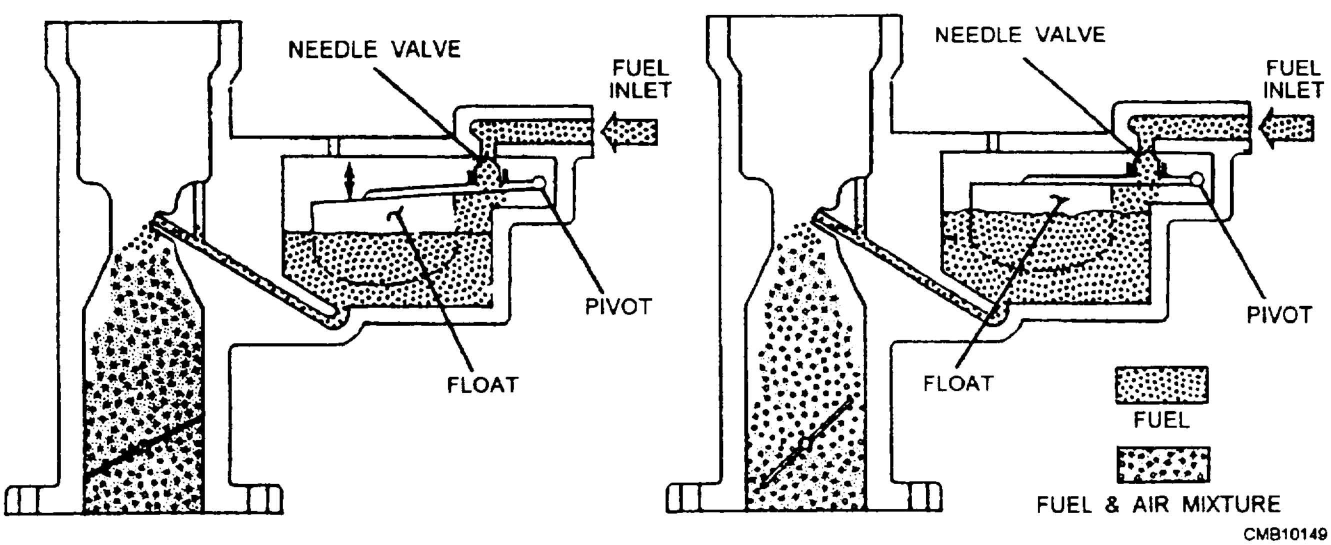

Figure 4-20.—Float system.

Idle System

The carburetor idle system (fig. 4-21) provides the air-fuel mixture at speeds below approximately 800 rpm or 20 mph When the engine is idling, the throttle is almost closed Air flow through the air horn is restricted to produce enough vacuum in the venturi. Since venturi vacuum is too low to pull fuel from the main discharge tube, the high intake manifold vacuum BELOW the throttle plate and the idle circuit are used to feed fuel into the air horn.

The fundamental parts of the carburetor idle system include a section of the main discharge tube, a low-speed jet, an idle air bleed, a bypass, a idle passage, an economizer, an idle screw port, and an idle mixture screw.

- The LOW-SPEED JET is a restriction in the idle passage that limits maximum fuel flow in the idle system. It is placed in the fuel passage before the idle air bleed and economizer.

- The IDLE AIR BLEED works with the economizer and bypass to add air bubbles in the fuel flowing to the idle port. The air bubbles help break up or atomize the fuel. This makes the air-fuel mixture burn more efficiently once it is in the engine.

- The IDLE PASSAGE carries the air-fuel slurry (mixture of liquid and air bubbles) to the idle screw port.

- The IDLE SCREW PORT is an opening into the air horn below the throttle valve.

- The IDLE MIXTURE SCREW allows adjustment of the size of the opening in the idle screw port. Turning the screw IN reduces the size of the idle port and the amount of fuel entering the horn. Turning the screw OUT increases the size of the idle port and enriches the fuel mixture at idle.

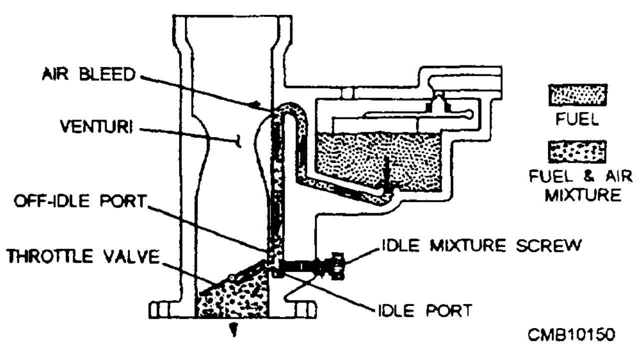

Figure 4-21.—Idle system.

Most modern carburetors have sealed idle mixture screws that are NOT normally adjusted. The seal prevents tampering with the factory settings of the idle mixture. Sometimes a plastic limiter cap is pressed over the idle mixture screws. They restrict how far the screws can be adjusted toward the rich or lean settings. Correcting idle screw adjustment on modern carburetors is critical to proper exhaust emission.

The basic operation of the idle system is as follows:

- At idle, fuel flows out of the fuel bowl, through the main discharge tube, and into the low-speed jet. The low-speed jet restricts maximum fuel flow.

- At the bypass, outside air is pulled into the idle system. This partially atomizes the fuel into slurry. As the air and fuel bubbles pass through the economizer, the air bubbles are reduced in size to further improve mixing.

- The fuel and air slurry then enters the idle screw port. The setting of the idle screw controls how much fuel enters the air horn at idle.

- With the throttle plate closed, high intake manifold pressure pulls fuel out of the idle system.

Off Idle System

The off idle, also known as the part throttle, feeds more fuel into the air horn when the throttle plate is partially open. It is an extension of the idle system. It functions above approximately 800 rpm or 20 mph. Without the off idle system, the fuel mixture would become too lean slightly above idle. The idle system alone is not capable of supplying enough fuel to the air stream passing through the carburetor. The off idle system helps supply fuel during the change from idle to high speed.

Basic off idle system operation is as follows:

- The driver presses down on the accelerator and cracks open the throttle plate. As the throttle plate swings open, the off idle ports are exposed to intake manifold vacuum.

- Vacuum then begins to pull fuel out of the idle screw and the off idle port. This action provides enough extra fuel to mix with the additional air flowing around the throttle plate.

Acceleration System

The carburetor acceleration system, like the off idle system, provides extra fuel when changing from the idle system to the high-speed system. The acceleration system squirts a stream of fuel into the air horn when the fuel pedal is pressed and the throttle plates swing open. Without the acceleration system, too much fuel would rush into the engine, as the throttle quickly opened. The mixture would become too lean for combustion and the engine would STALL or HESITATE. The acceleration system prevents a lean air-fuel mixture from upsetting a smooth increase in engine speed.

The basic parts of the acceleration system are the pump linkage, the accelerator pump, the pump check ball, the pump reservoir, the pump check weight, and the pump nozzle.

- The ACCELERATOR PUMP develops the pressure to force fuel out of the pump nozzle and into the air horn. There are two types of accelerator pumps—piston and diaphragm type (figs. 4-22 and 4-23).

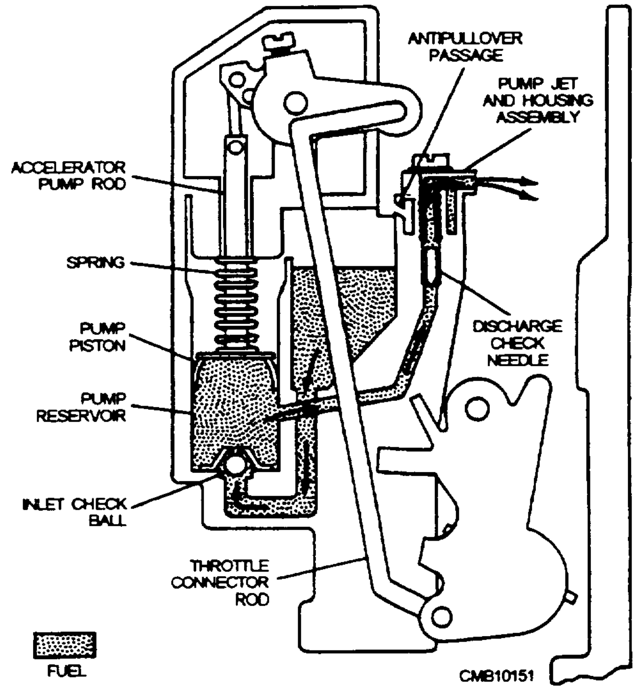

Figure 4-22.—Piston accelerator pump.

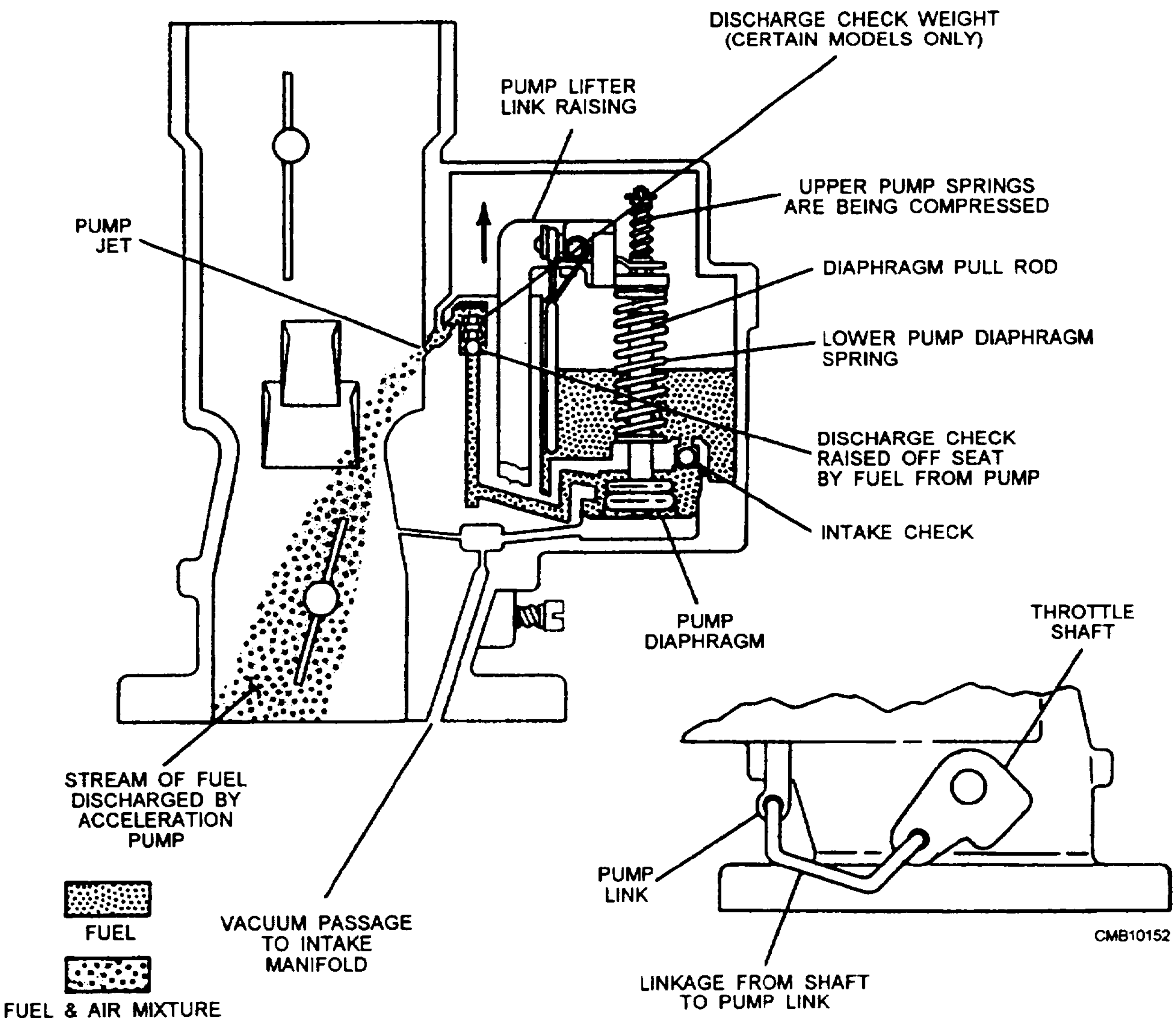

Figure 4-23.—Diaphragm accelerator pump.

- The PUMP CHECK BALL only allows fuel to flow into the pump reservoir. It stops fuel from flowing back into the fuel bowl when the pump is actuated.

- The PUMP CHECK WEIGHT prevents fuel from being pulled into the air horn by venturi vacuum. Its weight seals the passage to the pump nozzle and prevents fuel siphoning.

- The PUMP NOZZLE, also known as the pump jet, has a fixed opening that helps control fuel flow out of the pump. It also guides the fuel stream into the center of the air horn.

The basic operation of the acceleration system is as follows:

- The pump piston or diaphragm is pushed down in the pump chamber, as the throttle plate is opened, forcing fuel through the outlet passage.

- At the same moment, the pump check ball will seat, keeping fuel from being pumped back into the float bowl.

- The pump check weight will be forced off its seat, allowing fuel to pass to the pump discharge nozzle, and then discharged into the carburetor.

- The pump piston or diaphragm is raised in the pumping chamber when the throttle plate is closed, causing the pump check weight to seat blocking the outlet passageway.

- At the same time, the pump check ball is pulled off its seat and fuel is pulled into the pump chamber from the float bowl.

- The pump chamber is filled with fuel and ready for discharge whenever the throttle plate is opened.

The linkage between the accelerator pump and the throttle cannot be solid. If it were, the pump would act as a damper, not allowing the throttle to be opened and closed readily. The linkage activates the pump through a slotted shaft When the throttle is closed, the pump is held by its linkage. When the throttle is open, the pump is activated by being pushed down by a spring that is called a duration spring (fig. 4-24). The tension of the duration spring controls the length of time that the stream of fuel lasts. The spring is calibrated to specific applications. Too much spring pressure will cause fuel to be discharged too quickly, resulting in reduced fuel economy. Too little spring pressure will result in the fuel being discharged too slowly, causing engine hesitation.

High-Speed System

The, high-speed system, also called the main metering system, supplies the engine air-fuel mixture at normal cruising speeds. This system begins to function when the throttle plate is opened wide enough for the venturi action. Air flow through the carburetor must be relatively high for venturi vacuum to draw fuel out of the main discharge tube. The high-speed system

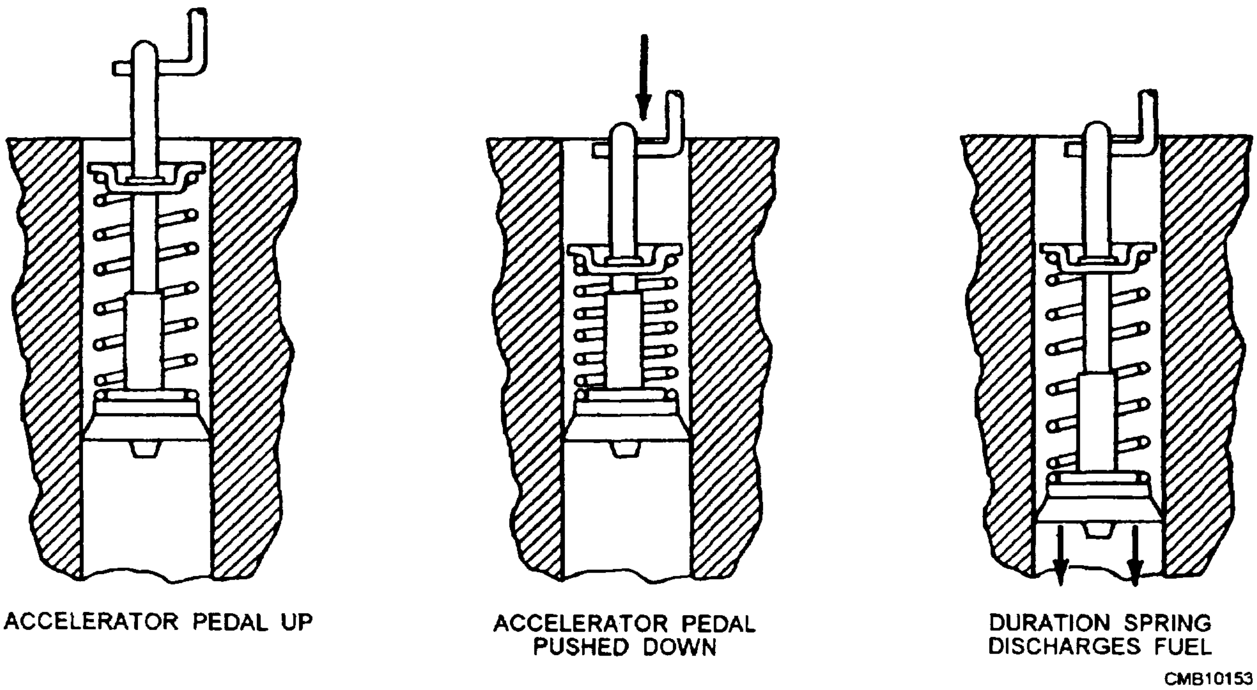

Figure 4-24.—Duration spring.

provides the leanest, most fuel efficient air-fuel ratio. It functions from about 20 to 55 mph or 2,000 to 3,000 rpm.

The high-speed system is the simplest system. It consists of the high-speed jet, the main discharge passage, the emulsion tube, the air bleed, and the venturi.

- The HIGH-SPEED JET is a fitting with a precision hole drilled into the center. This fitting screws into a threaded hole in the fuel bowl. One jet is used for each air horn. The hole size determines how much fuel flows through the system. A number is stamped on the high-speed jet to denote the diameter of the hole. Since jet numbering systems vary, refer to the manufacturer's manual for information on jet size.

- The EMULSION TUBE and AIR BLEED add air to the fuel flowing through the main discharge tube. The premixing of air with fuel helps the fuel atomize, as it is discharged into the air horn.

- The VENTURI is the hourglass shape, formed in the side of the carburetor air horn. One or two booster venturis (fig. 4-25) can be added inside the primary venturi to increase vacuum at lower engine speeds.

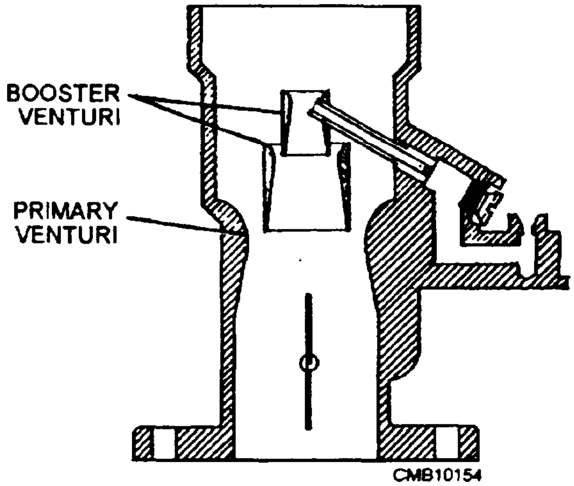

Figure 4-25.—Booster venturi

The basic operation of the high-speed system is as follows:

- When the engine speed is high enough, air flow through the carburetor forms a high vacuum in the venturi. The vacuum pulls fuel through the main metering system.

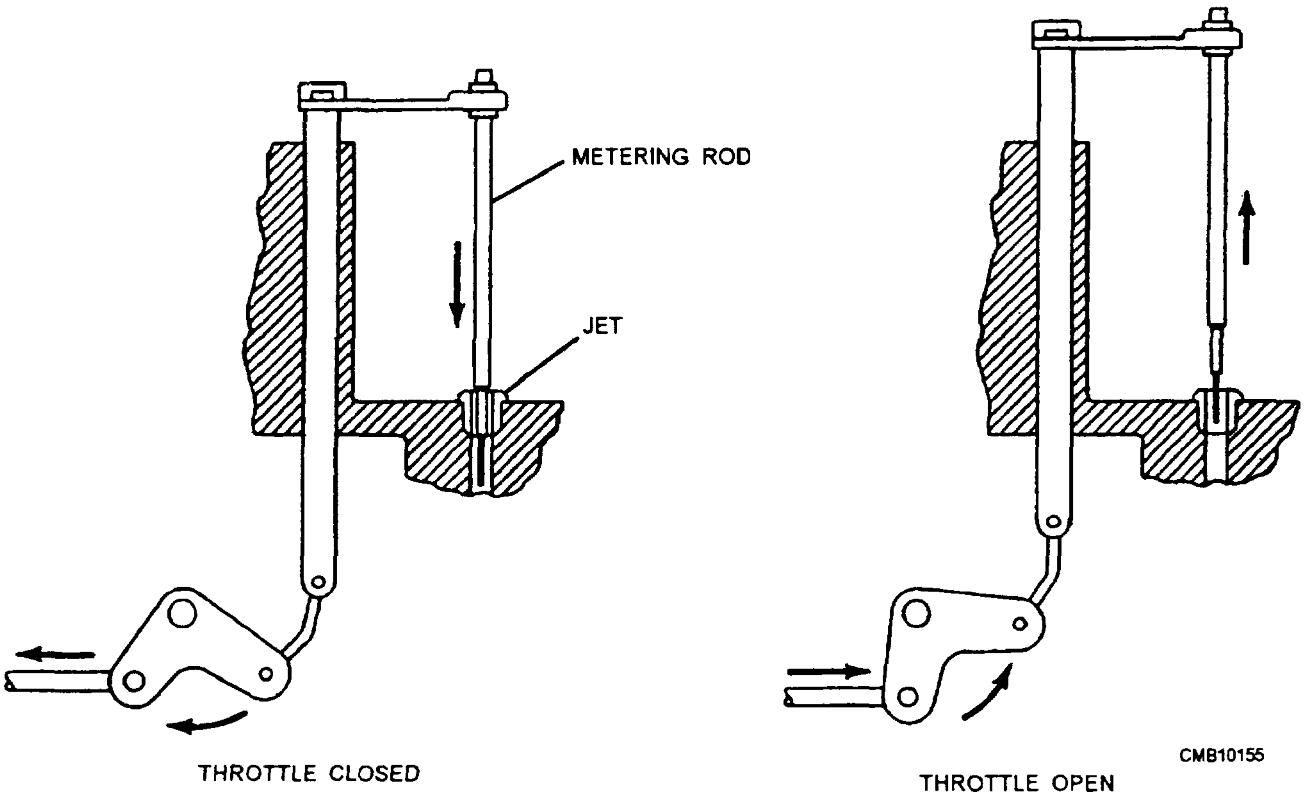

Figure 4-26.—Mechanically operated metering rod.

- The fuel flows through the main jet that meters the amount of fuel entering the system. The fuel then flows into the main discharge tube and emulsion tube.

- The emulsion tube causes air from the air bleed to mix with the fuel. The fuel, mixed with air, is finally pulled out the main nozzle and into the engine.

Full-Power System

The full-power system provides a means of enriching the fuel mixture for high-speed, high-power conditions. This system operates, for example, when the driver presses the fuel pedal to pass another vehicle or to climb a steep hill. The full-power system is an addition to the high-speed system. Either a metering rod or a power valve (jet) can be used to provide variable, high-speed air-fuel ratio.

A metering rod is a stepped rod that moves in and out of the main jet to alter fuel flow. When the rod is down inside the jet, flow is restricted and a leaner fuel mixture results. When the rod is pulled out of the jet, flow is increased and a richer fuel mixture results for more power output. The metering rod is either mechanical-linkage or engine-vacuum operated.

- The MECHANICAL LINKAGE metering rod (fig. 4-26) is linked to the throttle lever. Whenever the throttle is opened wide, the linkage lifts the metering rod out of the jet. When the throttle is closed, the linkage lowers the metering rod into the jet.

- 'The VACUUM OPERATED metering rod (fig. 4-27) that is controlled by engine vacuum is connected to a diaphragm. At steady speeds, power demands are low and engine vacuum is high, and the piston pushes the metering rod into the jet against spring pressure, restricting the flow to the discharge tube. When the load increases, vacuum decreases, causing the piston spring to lift the metering rod out of the jet, progressively increasing the flow of fuel to the discharge tube.

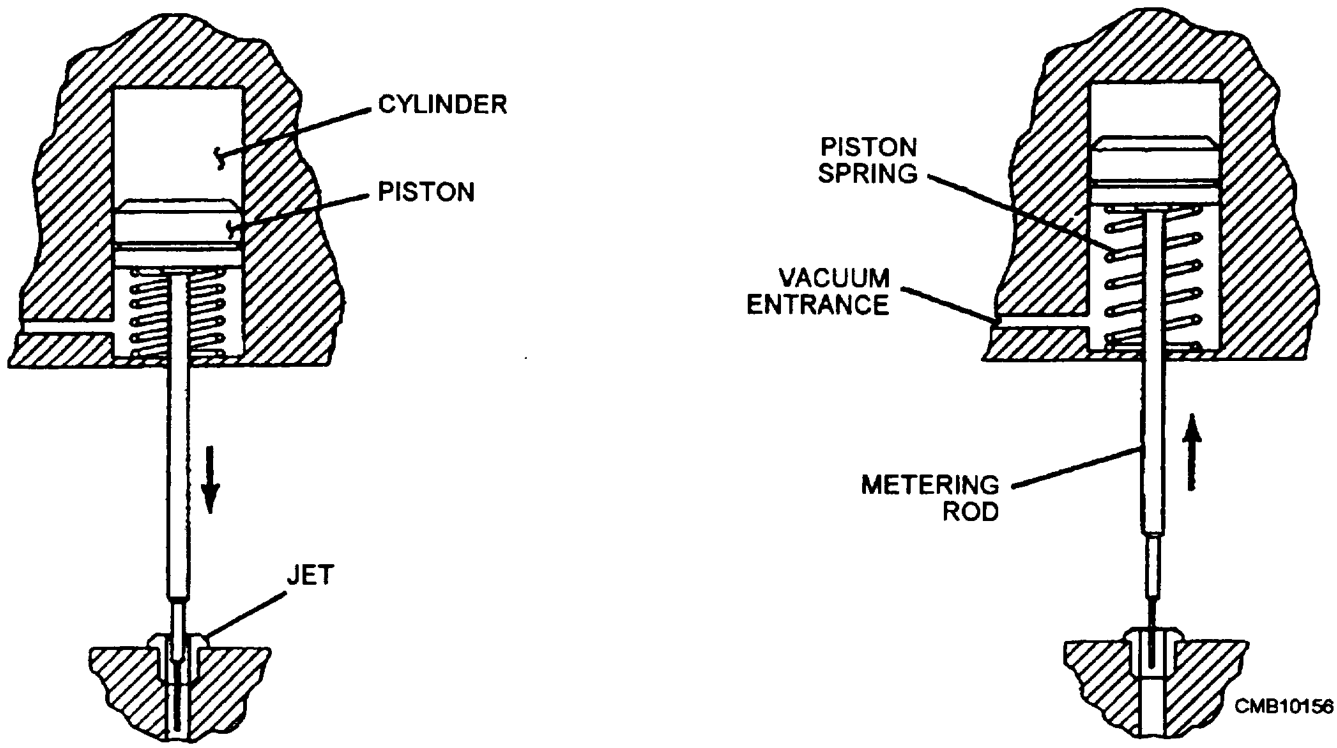

Figure 4-27.—Vacuum operated metering rod.

A vacuum power jet valve (fig. 4-28), also known as an economizer, performs the same function as a metering rod; it provides a variable high-speed fuel mixture. A power jet valve consists of a fuel valve, a vacuum diaphragm, and a spring. The spring holds the power valve in the normally OPEN position. A vacuum passage runs to the power valve diaphragm. When the power valve is open, it serves as an extra jet that feeds fuel into the high-speed system.

When the engine is cruising at normal highway speeds, engine intake manifold vacuum is high. This vacuum acts on the power valve diaphragm and pulls the fuel valve closed. No additional fuel is added to the metering system under normal conditions; however, when the throttle plate is swung open for passing or climbing a hill, engine vacuum drops. The spring in the power valve can push the fuel valve open. Fuel flows through the power valve and into the main metering system, adding more fuel for more engine power.

Choke System

When the engine is cold, the fuel tends to condense into large drops in the manifold, rather than vaporizing. By supplying a richer mixture (8:1 to 9:1), there will be enough vapor to assure complete combustion. The carburetor is fitted with a choke system to provide this richer mixture. The choke system provides a very rich mixture to start the engine and to make the mixture less rich gradually, as the engine reaches operating temperature. The two types of choke systems are the manual and automatic:

- The manual choke system (fig. 4-29) was once the most popular way of controlling the choke plate; however, because of emissions regulations the possible danger when used with catalytic converters and technological advances in automatic choke systems, manual chokes are not often used today. In the manual choke system, the choke plate is operated by a flexible cable that extends into the operator's compartment. As the control is pulled out, the choke plate will be closed, so the engine can be started. As the control is pushed back in, the position of the choke plate is adjusted to provide the proper mixture. The following are two features that are incorporated into the manual choke to reduce the possibility of the engine flooding by automatically admitting air into the engine.

- A spring-loaded poppet valve (fig. 4-30) that is automatically pulled open by the force of the engine intake strokes.

- An off-center choke valve (fig. 4-31) that creates a pressure differential between the two sides of the choke plate when it is subjected to engine intake, causing it to be pulled open against the force of spring loaded linkage.

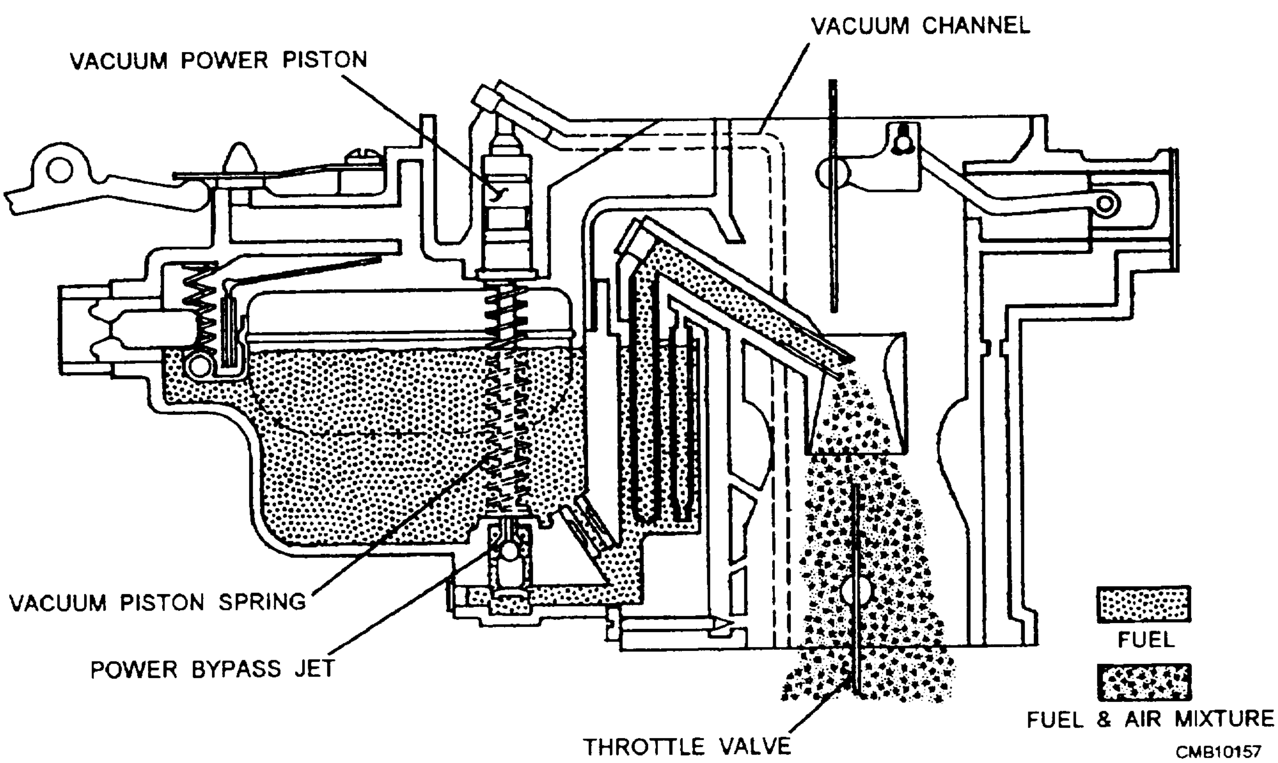

Figure 4-28.—Vacuum power jet.

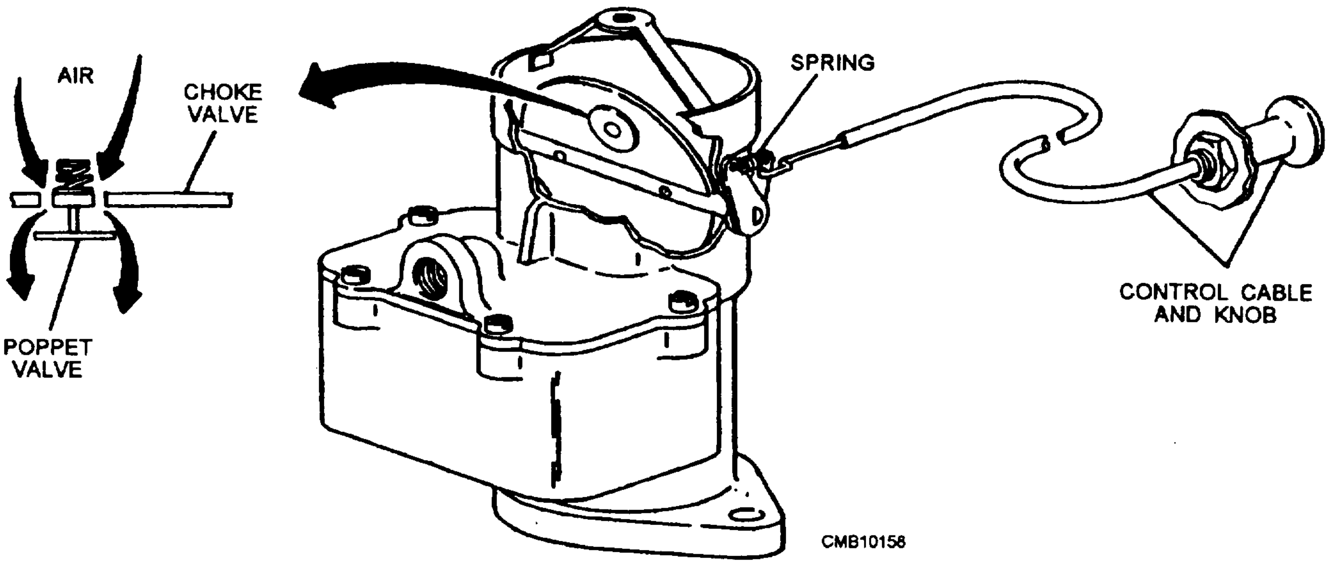

Figure 4-29.—Manual choke system.

- Automatic chokes (fig. 4-32) have replaced the conventional manual choke. They control the air-fuel ratio for quick starting at low temperature and also provide for the proper amount of choking to enrich the air-fuel mixture for all conditions of engine operation

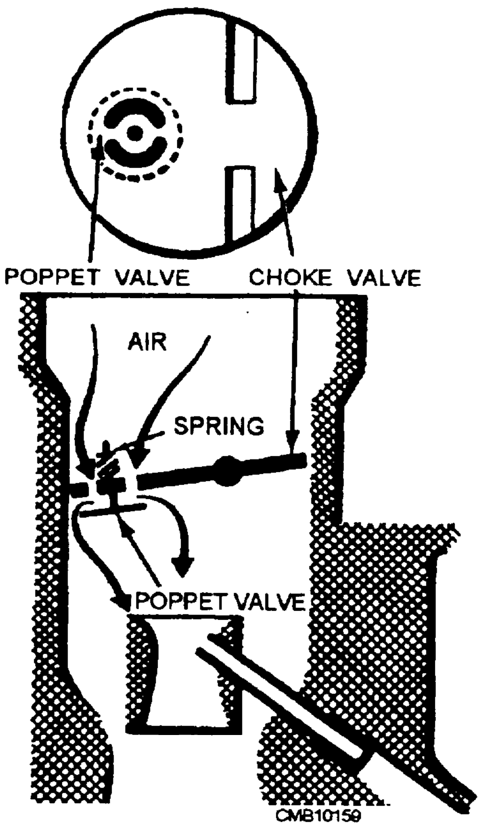

Figure 4-30.—Spring-loaded poppet valve in the choke valve.

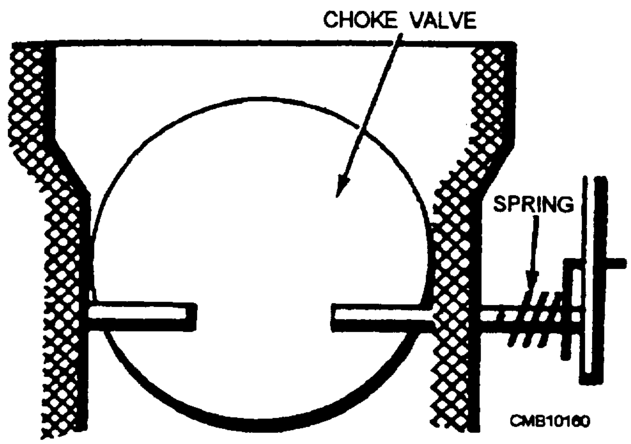

Figure 4-31.—Off center choke valve.

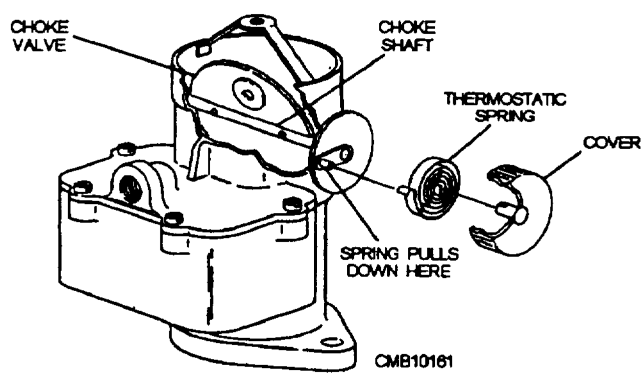

Figure 4-32.—Automatic choke.

during the warm-up period. An automatic choke system has a choke plate (valve), a thermostatic spring, and other parts depending upon choke design.

- The choke plate is a butterfly (disc) valve near the top of the carburetor air horn. When the choke plate is closed, it blocks normal air flow through the carburetor.

- The thermostatic spring is a bimetal spring (spring made of two dissimilar metals) which may be used to open and close the choke. The two metals have a different rate of expansion that make the spring coil tighter when cold and uncoils when heated. This coiling-uncoiling action is used to operate the choke.

The basic operation of the automatic choke system is as follows:

- With the engine cold, the thermostatic spring holds the choke closed. When the engine is started, the closed choke causes high vacuum in the carburetor air horn. This pulls a large amount of fuel out of the main discharge tube.

- As the engine and thermostatic spring warm, the spring uncoils and opens the choke plate. ‘This action produces a leaner mixture. A warm engine will not run properly if the choke were to remain closed.

Various methods are used to control the warming of the choke thermostatic spring. The four methods of providing controlled heat to the thermostatic spring are as follows: electricity, engine coolant, well-type heated, and exhaust manifold.

- ELECTRICITY (fig. 4-33) uses an electric coil to heat the thermostatic spring. The heating coil is switched on with the ignition switch. Some systems use a control unit that prevents power from reaching the electric coil until the engine compartment reaches a desired temperature.

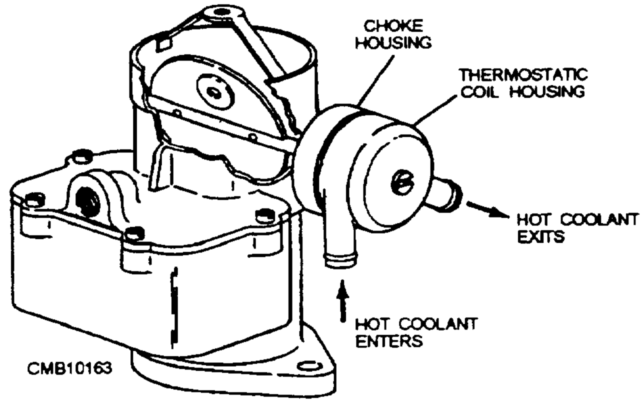

Figure 4-34.—Engine coolant heated choke.

- ENGINE COOLANT (fig. 4-34) uses a passage in the thermostat housing to circulate engine coolant for heating the thermostatic spring.

- WELL-TYPE HEATED (fig. 4-35) mounts the thermostatic spring in the top of the exhaust manifold. As the engine and manifold warms, the thermostatic spring uncoils to open the choke.

- The EXHAUST MANIFOLD (fig. 4-36) uses heat from the exhaust manifold to heat the thermostatic spring. The exhaust heat is brought to the choke through the means of a heat tube. The heat tube passes through the exhaust manifold, so as it takes in fresh air via the choke stove, it picks up heat from the exhaust without sending any actual exhaust fumes to the choke mechanism.

When the choke system is operating during warm-up, the engine must run at a faster idle speed to improve drivability and prevent flooding. To accomplish this, fit

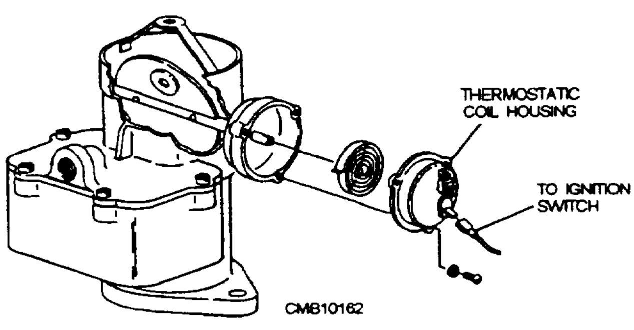

Figure 4-33.—Electric choke.

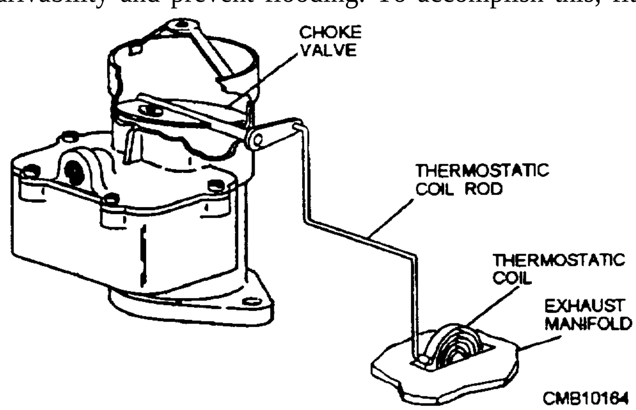

Figure 4-35.—Well-type exhaust-heated choke.

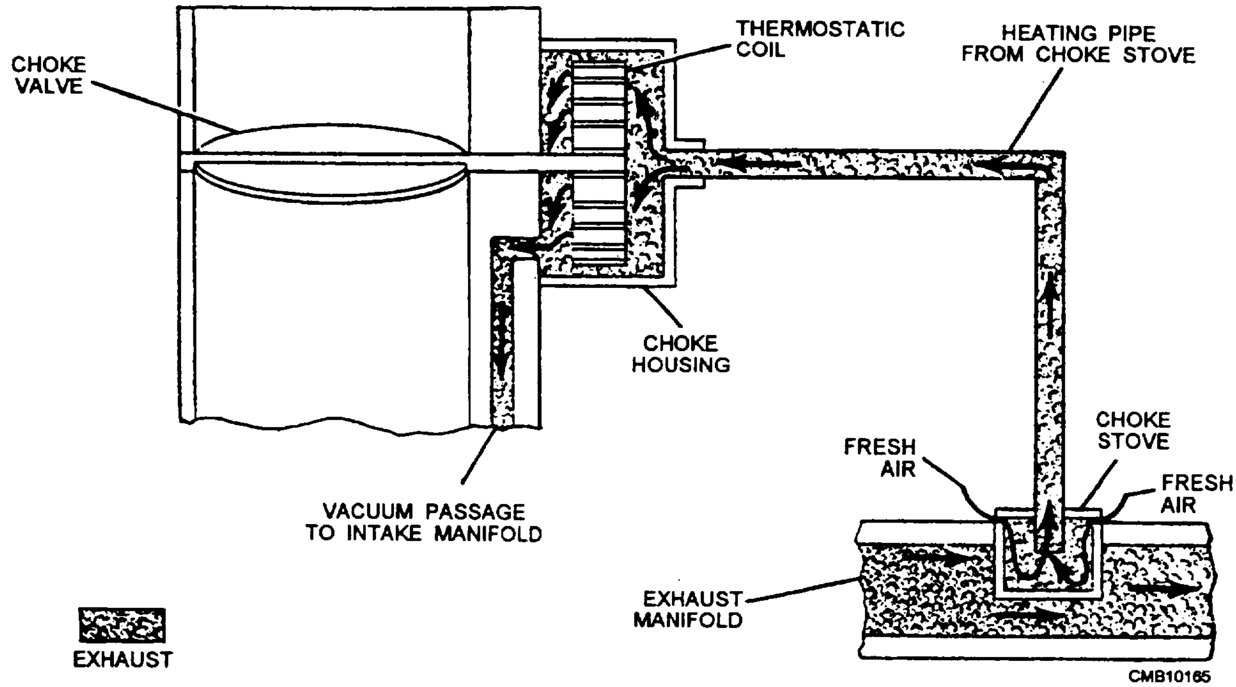

Figure 4-36.—Exhaust-manifold heat-tube choke.

the carburetor with a fast idle cam (fig. 4-37) that is operated by linkage from the choke.

When the choke closes, the fast idle cam swings around in front of the fast idle screw. As a result, the fast idle cam and fast idle screw prevent the throttle plate from closing. Engine idle speed is increased to smooth cold engine operation and prevents stalling. As soon as the engine warms, the choke opens and the fast idle cam is deactivated. When the throttle is opened, the choke linkage swings away from the fast idle screw and the engine returns to curb idle (normal, hot idle speed).

If for some reason the engine should flood when it is cold, a device is needed to open the choke, so air may be admitted to correct the condition. This is accomplished

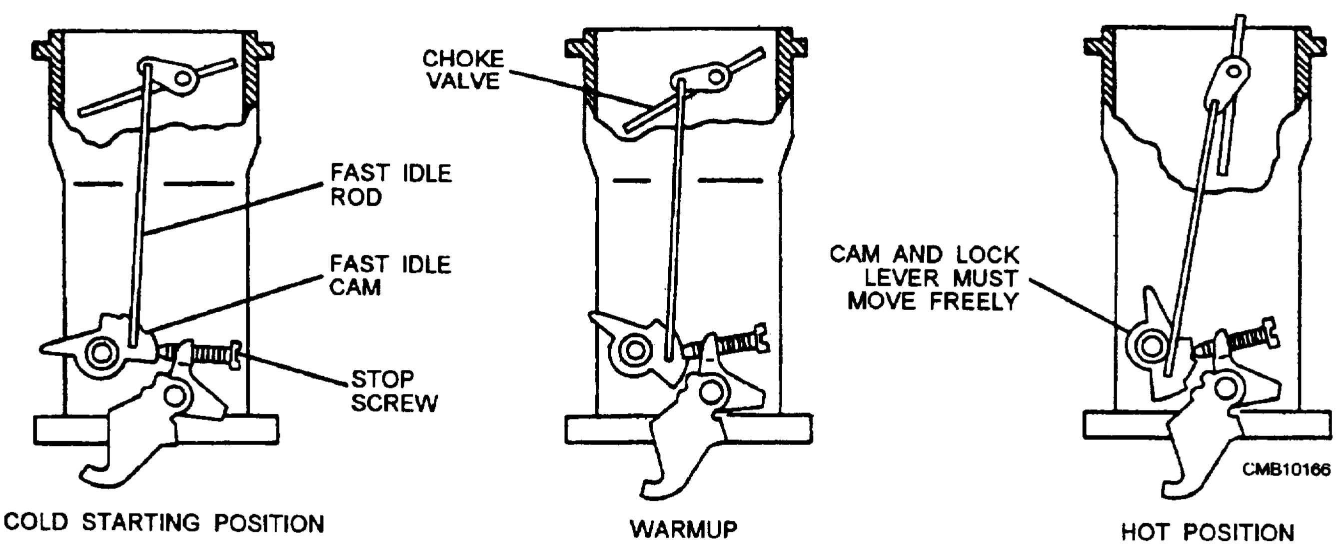

Figure 4-37.—Fast idle cam operation.

by the choke unloader (fig. 4-38). The choke unloader can be either mechanical- or vacuum-operated.

A mechanical choke unloader physically opens the choke plate any time the throttle swings fully open. It uses a metal lug on the throttle lever. When the throttle lever moves to the fully opened position, the lug pushes on the choke linkage (fast idle linkage). This provides the operator a means of opening the choke. Air can then enter the air horn to help clear a flooded engine (engine with too much liquid fuel in the cylinders and intake manifold).

A vacuum choke unloader (fig. 4-39). also called a choke brake, uses engine vacuum to crack open the choke plate as soon as the engine starts. It automatically prevents the engine from flooding.

Before the engine starts, the choke spring holds the choke plate almost completely closed. This action primes the engine with enough fuel for starting. Then as the engine starts, the intake manifold vacuum acts on the choke brake diaphragm. The diaphragm pulls the choke linkage and lever to swing the choke plate open slightly. This action helps avoid an overly rich mixture and improves cold engine drivability.

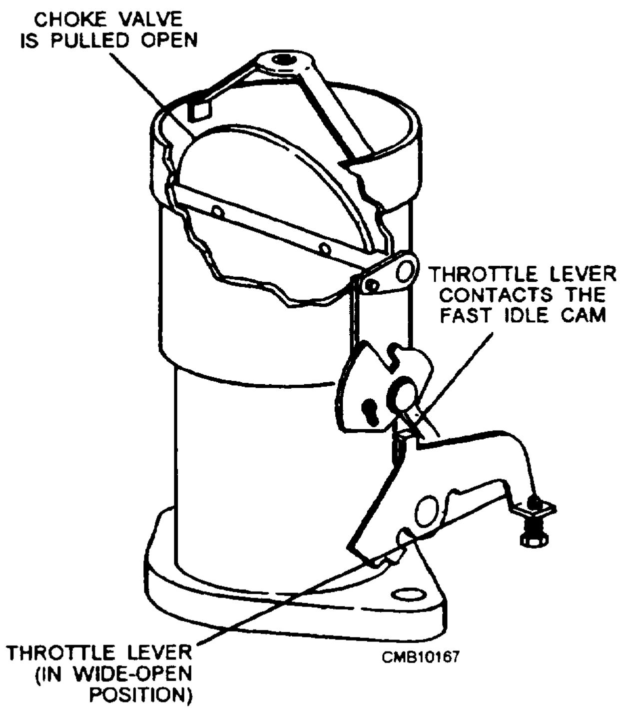

Figure 4-38.—Choke unloader.

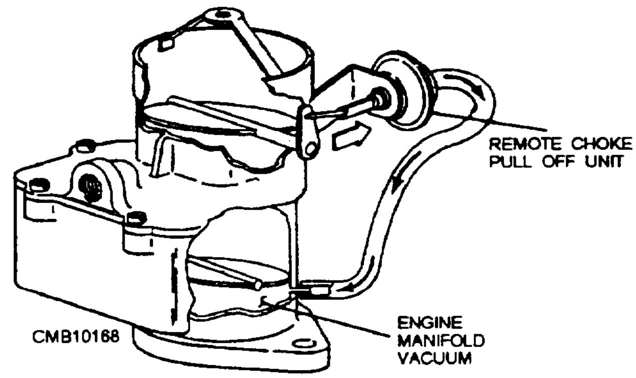

Figure 4-39.—Vacuum choke unloader.

CARBURETOR ACCESSORIES

There are several devices used on carburetors to improve drivability and economy. These devices are as follows: the fast idle solenoid, the throttle return dashpot, the hot idle compensator, and the altitude compensator. Their applications vary from vehicle to vehicle.

Fast Idle Solenoid

A fast idle solenoid, also known as an antidieseling solenoid (fig. 4-40), opens the carburetor throttle plates during engine operation but allows the throttle plates to close as soon as the engine is turned off. In this way, a faster idle speed can be used while still avoiding dieseling (engine keeps running even though the ignition key is turned off). This is a particular problem with newer emission controlled vehicles due to higher operating temperatures, higher idle speeds, leaner fuel mixtures, and lower octane fuel.

When the engine is running, current flows to the fast idle solenoid, causing the plunger to move outward. The throttle plates are held open to increase engine speed. The plunger is adjustable, so the idle speed can be adjusted. When the engine is turned off, current flow to the solenoid stops. The solenoid plunger retracts and the throttle plates are free to swing almost closed.

Throttle Return Dashpot

The throttle return dashpot, also known as an antistall dashpot (fig. 4-41), acts as a damper to keep the throttle from closing too quickly when the accelerator pedal is suddenly released. It is commonly used on carburetors for automatic transmission equipped vehicles.

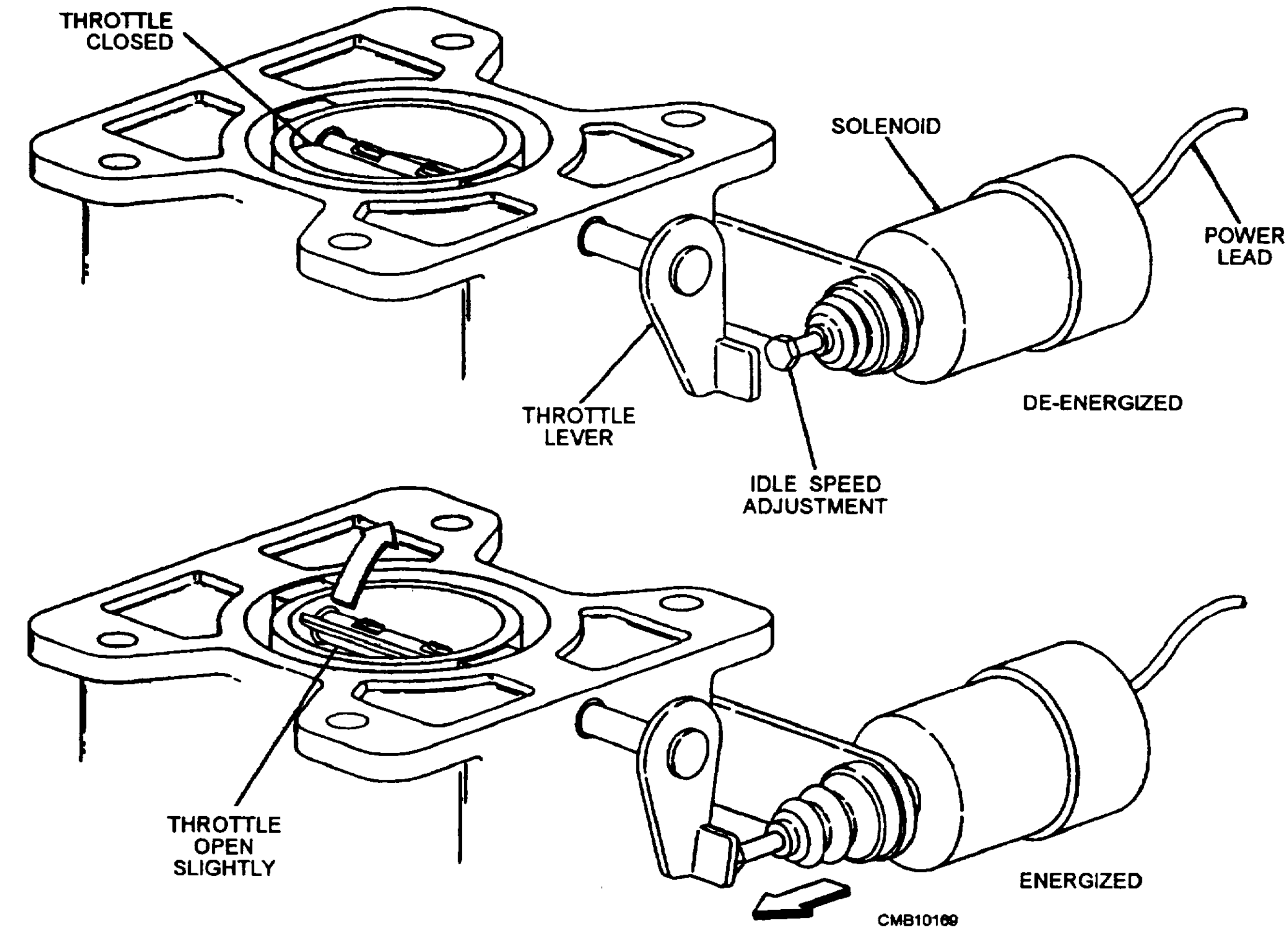

Figure 4-40.—Antidieseling solenoid operation.

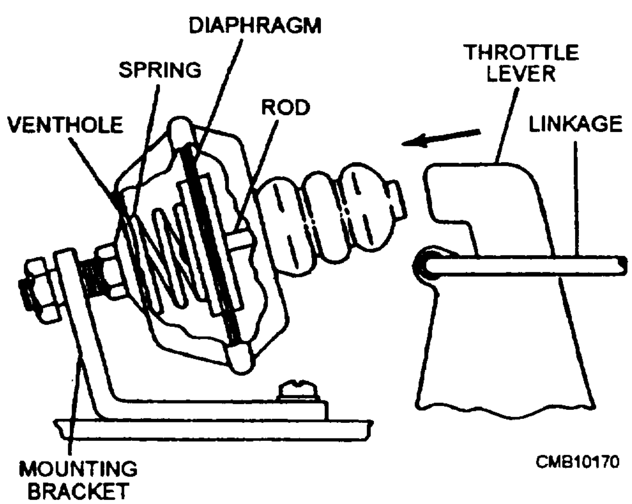

Figure 4-41.—Throttle return dashpot

Without the throttle return dashpot, the engine could stall when the engine quickly returned to idle. The drag of the automatic transmission could kill the engine.

The throttle return dashpot works something like a shock absorber. It uses a spring-loaded diaphragm mounted in a sealed housing. A small hole is drilledinto the diaphragm housing to prevent rapid movement of the dashpot plunger and diaphragm. Air must bleed out of the hole slowly.

When the vehicle is traveling down the road (throttle plates open), the spring pushes the dashpot plunger forward. When the engine returns to idle, the throttle lever strikes the extended dashpot plunger, and air leaks out of the throttle return dashpot, returning the engine slowly to curb idle. This action gives the automatic transmission enough time to disconnect (torque converter releases) from the engine without the engine stalling.

Hot Idle Compensator

A hot idle compensator (fig. 4-42) is a thermostatically controlled device that prevents engine stalling or a rough idle under high engine temperatures. The temperature sensitive valve admits extra air into the engine to increase idle speed and smoothness.

At normal engine temperatures, the hot-idle compensator valve remains closed, and the engine idles normally. When temperatures are high (prolonged idling periods, for example), fuel vapors can enter the air horn and enrich the air-fuel mixture. The hot idle compensator opens to allow extra air to enter the intake manifold. This action compensates for the extra fuel vapors and corrects the air-fuel mixture.

Altitude Compensator

An altitude compensator is used to change the air-fuel mixture in the carburetor with changes in the vehicle height above sea level. Normally the compensator is an aneroid device (bellows device that expands and contracts with changes in atmospheric pressure).

As a vehicle is driven up a mountain, the density of the air decreases. This condition tends to make the air-fuel mixture richer. The reduced air pressure causes the aneroid to expand, opening an air valve. Extra air flows into the air horn and the air-fuel mixture becomes leaner. The opposite occurs when the vehicle descends from the mountain. The greater air density and pressure tends to make the carburetor mixture too lean. The increased air pressure collapses the aneroid and the air valve closes. This action enriches the mixture enough to compensate for the low altitude.

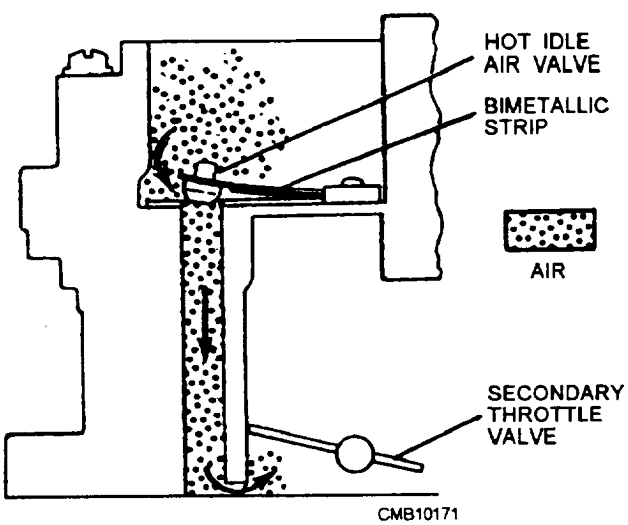

Figure 4-42.—Hot idle compensator.

COMPUTER-CONTROLLED CARBURETORS

A computer-controlled carburetor uses a solenoid-operated valve to respond to commands from the microcomputer (electronic control unit). The system uses various sensors to send information to the computer that calculates how rich or lean to set the carburetor air-fuel mixture. The system is also known as a computer controlled emission system which consists of the following: oxygen sensor, temperature sensor, pressure sensor, electromechanical carburetor, mixture control solenoid, computer, and idle speed actuator. The function of each is as follows:

- The OXYGEN SENSOR, or exhaust gas sensor, monitors the oxygen content in the engine exhaust. The amount of oxygen in the exhaust indicates the richness (low oxygen content) or leanness (high oxygen content) of the air- fuel mixture. The sensor voltage output changes with any change in oxygen content in the exhaust gases.

- The TEMPERATURE SENSOR detects the operating temperature of the engine. Its resistance changes with the temperature of the engine. The change in resistance allows the computer to enrich the fuel mixture during cold engine operations.

- The MANIFOLD PRESSURE SENSOR (MAP) measures intake manifold vacuum and engine load. High engine load or power output causes intake manifold vacuum to drop. The pressure sensor then signals the computer with a change in resistance and current flow. As manifold pressure drops, the computer increases the air-fuel mixture for added power. As the manifold pressure increases, the computer makes the carburetor setting leaner for improved economy.

- The ELECTROMECHANICAL CARBURETOR has both electrical and mechanical control devices. It is commonly used with a computer control system.

- The MIXTURE CONTROL SOLENOID alters the air-fuel mixture in the electromechanical carburetor. Electrical signals from the computer activate the solenoid to open and close air and fuel passages in the carburetor.

- The COMPUTER, also called the electronic control unit (ECU), uses sensor information to operate the mixture control solenoid of the carburetor.

- The IDLE SPEED ACTUATOR is a tiny electric motor and gear mechanism that allows the computer to change engine idle speed by holding the throttle lever in the desired position.

Many of the components and sensors are also used in gasoline fuel injection systems, which we will discuss later in this chapter.

In a computer-controlled carburetor, the air-fuel ratio is maintained by cycling the mixture solenoid ON and OFF several times a second. Control signals from the computer are used to meter different amounts of fuel out of the carburetor. When the computer sends a rich command to the solenoid, the signal voltage to the mixture solenoid is in the OFF position more than it is ON, causing the solenoid to stay open more. During a lean signal the mixture solenoid has more ON time, causing less fuel to pass through the solenoid valve and the mixture becomes leaner.

NOTE

Computerized carburetor systems vary. For exact detail on a particular system, refer to the manufacturer's service manual, which will explain how the specific system functions.

CARBURETOR TROUBLES

Some of the engine troubles that can usually (but not ALWAYS) be traced to some fault in the carburetor system are as follows:

- EXCESSIVE FUEL CONSUMPTION can result from a high float level, a leaky float, a sticking metering rod or full power piston, a sticking accelerator pump, and/or too rich of an idling mixture.

- A SLUGGISH ENGINE may be the result of a poorly operating accelerator pump, a low float level, dirty or gummy fuel passages, or a clogged air cleaner.

- POOR IDLING, often characterized by a stalling of the engine, is usually due to a too rich idle mixture, a defective choke, or an incorrectly adjusted idle speed screw at the throttle plate.

- FAILURE OF THE ENGINE TO START may be caused by an incorrectly adjusted choke, clogged fuel lines, or air leak into the intake manifold.

- HARD STARTING OF A WARM ENGINE could be due to a defective or improperly adjusted throttle link.

- SLOW ENGINE WARM-UP may indicate a defective choke or defective radiator thermostat.

- SMOKY BLACK EXHAUST indicates a very rich air-fuel mixture.

- STALLING OF THE ENGINE AS IT WARMS could be caused by a defective choke or closed choke valve.

- A BACKFIRING ENGINE may be due to an incorrect, often lean, air-fuel mixture reaching the engine. In turn, this condition could be caused by a clogged fuel line or a fluctuating fuel level.

- An ENGINE RUNS BUT MISSES, the most likely cause is a vacuum leak at a vacuum hose or the intake manifold. In addition, it could be an improper air-fuel mixture reaching the engine due to clogged or worn carburetor jets or an incorrect fuel level in the float bowl.

Several quick checks can be made to see how well the carburetor is working. More accurate analysis requires test instruments, such as an exhaust gas analyzer and an intake manifold vacuum gauge. The quick checks are as follows:

1. FLOAT LEVEL ADJUSTMENT. With the engine warmed up and running at idle speed, remove the air cleaner. Carefully note the condition of the high-speed nozzle. If the nozzle tip is wet or is dripping fuel, the float level is probably too high. This could cause a continuous discharge of fuel from the nozzle, even at idle.

2. IDLE SYSTEM. If the engine does not idle smoothly after it is warmed up, the idle system could be at fault. Slowly open the throttle until the engine is running at about 3,000 rpm. If the speed does not increase evenly and the engine runs roughly through this speed range, the idle or main metering system is probably defective.

3. ACCELERATOR PUMP SYSTEM. With the air cleaner off and the engine not running, open the throttle suddenly. See if the accelerator pump system discharges a squirt of fuel into the air horn. The flow should continue for a few seconds after the throttle plate reaches the wide, open position.

4. MAIN METERING SYSTEM. With the engine warmed up and running at 2,000 rpm, slowly cover part of the air horn with a piece of stiff cardboard The engine should speed up slightly, since this action causes a normal operating main metering system to discharge more fuel.

WARNING

Do NOT use your hand to cover the air horn when performing this test.

Q5. *Name the seven basic carburetor systems?*

Q6. *What system maintains a steady working supply of fuel to a constant level in the carburetor?*

Q7. *What device acts as a damper to keep the throttle from closing too quickly when the accelerator pedal is suddenly released?*

Q8. *What sensor in a computerized carburetor system measures intake vacuum and engine load?*

GASOLINE FUEL INJECTION SYSTEMS

LEARNING OBJECTIVE: *Identify and describe the different gasoline fuel injection systems.*

A modern gasoline injection system uses pressure from an electric fuel pump to spray fuel into the engine intake manifold. Like a carburetor, it must provide the engine with the correct air-fuel mixture for specific operating conditions. Unlike a carburetor, however, PRESSURE, not engine vacuum, is used to feed fuel into the engine. This makes the gasoline injection system very efficient.

A gasoline injection system has several possible advantages over a carburetor type of fuel system. Some advantages are as follows:

- Improved atomization. Fuel is forced into the intake manifold under pressure that helps break fuel droplets into a fine mist.

- Better fuel distribution. Equal flow of fuel vapors into each cylinder.

- Smoother idle. Lean fuel mixture can be used without rough idle because of better fuel distribution and low-speed atomization.

- Lower emissions. Lean efficient air-fuel mixture reduces exhaust pollution.

- Better cold weather drivability. Injection provides better control of mixture enrichment than a carburetor.

- Increased engine power. Precise metering of fuel to each cylinder and increased air flow can result in more horsepower output.

- Fewer parts. Simpler, late model, electronic fuel injection system have fewer parts than modern computer-controlled carburetors.

There are many types of gasoline injection systems. Before studying the most common ones, you should have a basic knowledge of the different classifications. Systems are classified either single- or multi-point injection and indirect or direct injection.

The point or location of fuel injection is one way to classify a gasoline injection system. A single-point injection system, also call throttle body injection (TBI), has the injector nozzles in a throttle body assembly on top of the engine. Fuel is sprayed into the top center of the intake manifold

A multi-point injection system, also called port injection, has an injector in the port (air-fuel passage) going to each cylinder. Gasoline is sprayed into each intake port and toward each intake valve. Thereby, the term multi-point (more than one location) fuel injection is used.

An indirect injection system sprays fuel into the engine intake manifold. Most gasoline injection systems are of this type. Direct injection forces fuel into the engine combustion chambers. Diesel injection systems are direct type.

There are three basic configurations of gasoline fuel injection—timed, continuous, and throttle body.

TIMED FUEL INJECTION SYSTEM

Timed fuel injection systems for gasoline engines inject a measured amount of fuel in timed bursts that are synchronized to the intake strokes of the engine. ‘limed injection is the most precise form of fuel injection but is also the most complex. There are two basic forms of timed fuel injection-mechanical and electronic.

The basic operation of a mechanical-timed injection system (fig. 4-43) is as follows:

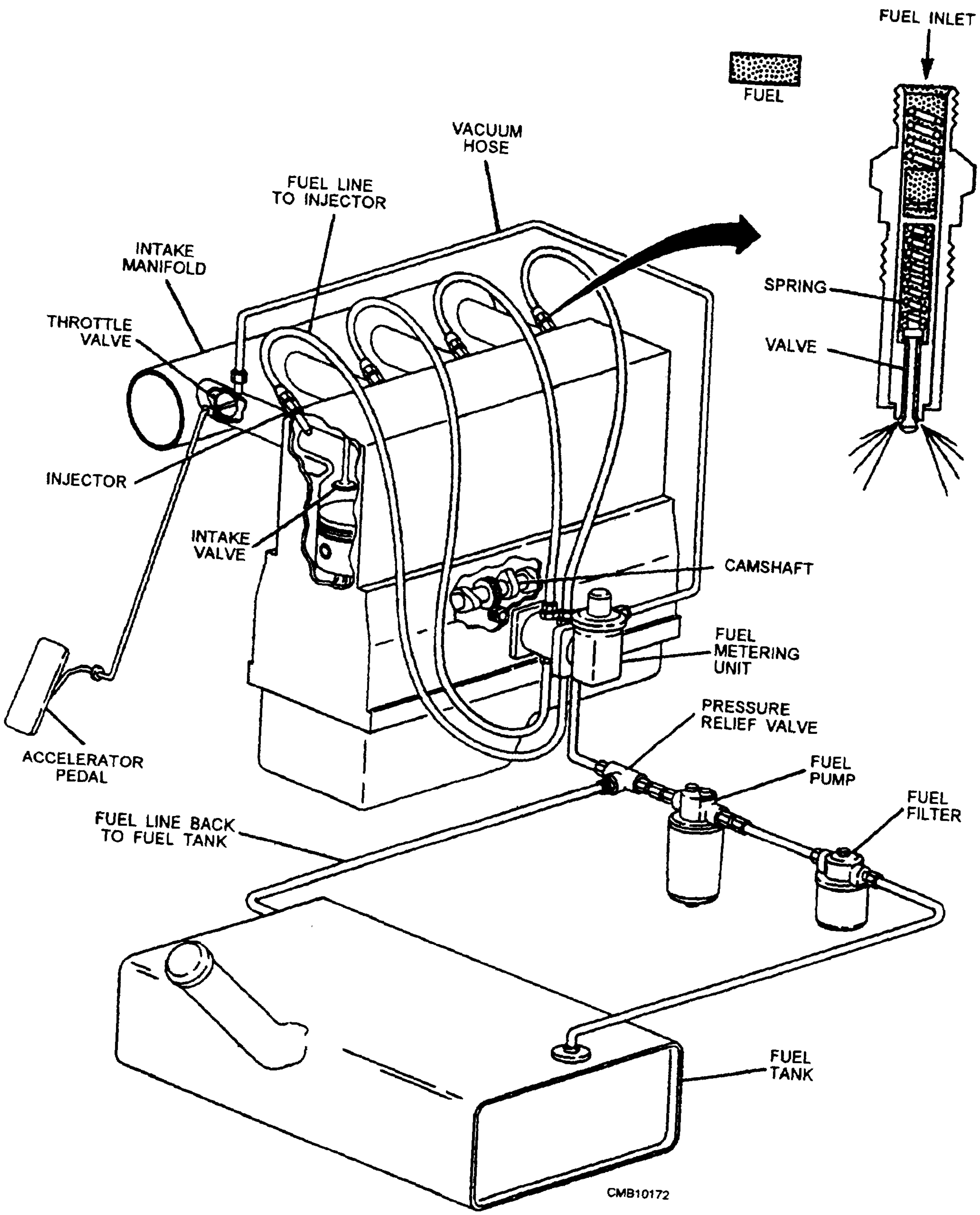

Figure 4-43.—Mechanical-timed injection.

- A high-pressure electric pump draws fuel from the fuel tank and delivers it to the metering unit. A pressure relief valve is installed between the fuel pump and the metering unit to regulate fuel line pressure by bleeding off excess fuel back to the tank.

- The metering unit is a pump that is driven by the engine camshaft. It is always in the same rotational relationship with the camshaft, so it can be timed to feed the fuel to the injectors just at the right moment.

- Each injector contains a spring-loaded valve that is opened by fuel pressure, injecting fuel into the intake at a point just before the intake valve.

- The throttle valve regulates engine speed and power output by regulating manifold vacuum, which, in turn, regulates the amount of fuel supplied to the injectors by the metering pump.

The more common type of timed fuel injection is the electronic-timed fuel injection, also known as electronic fuel injection (EFI) (fig. 4-44). Anelectronic fuel injection system can be divided into four subsystems:

1. Fuel delivery system
2. Air induction system
3. Sensor system
4. Computer control system

The fuel delivery system of an EFI system includes an electric fuel pump, a fuel filter, a pressure regulator, the injector valves, and the connecting lines and hoses.

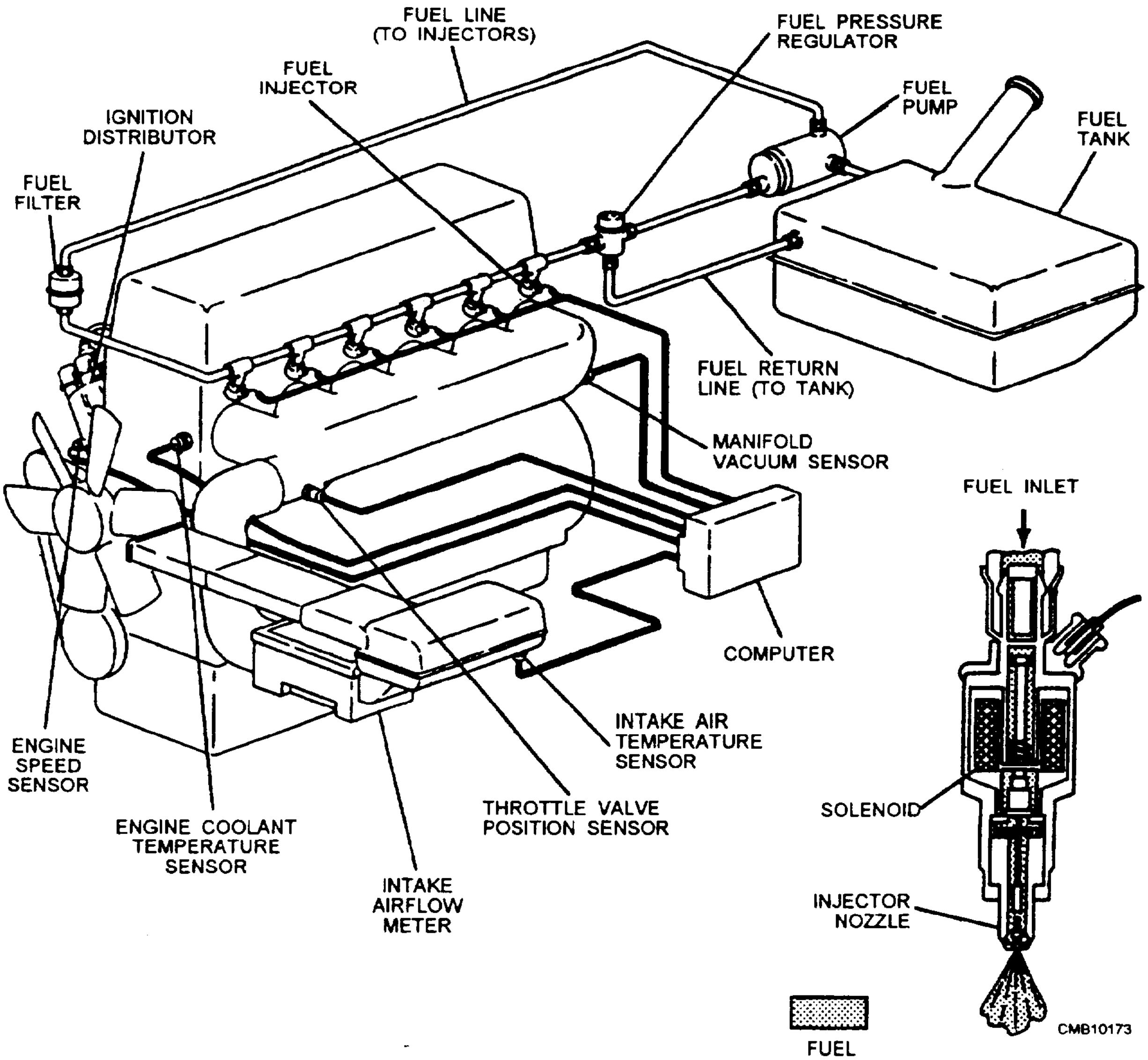

Figure 4-44.—Electronic-timed injection.

• The ELECTRIC FUEL PUMP draws fuel out of the tank and forces it into the pressure regulator.

• The FUEL PRESSURE REGULATOR controls the amount of pressure entering the injector valves. When sufficient pressure is attained, the regulator returns excess fuel to the tank. This maintains a preset amount of fuel pressure for injector valve operation.

• The FUEL INJECTOR for an EFI system is a coil or solenoid-operated fuel valve. When not energized, spring pressure keeps the injector closed, keeping fuel from entering the engine. When current flows through the injector coil or solenoid, the magnetic field attracts the injector armature. The injector opens, squirting fuel into the intake manifold under pressure.

The air induction system for the EFI typically consists of a throttle valve, sensors, an air filter, and connecting ducts.

The throttle valve regulates how much air flows into the engine. In turn, it controls engine power output. Like the carburetor throttle valve, it is connected to the gas pedal. When the pedal is depressed, the throttle valve swings open to allow more air to rush into the engine.

The EFI sensor system monitors engine operating conditions and reports this information to the computer. A sensor is an electrical device that changes circuit resistance or voltage with a change in a condition (temperature, pressure, position of parts, etc.). For example, the resistance of a temperature sensor may decrease as temperature increases. The computer can use the icreased current flow through the sensor to calculate any needed change in the injector valve opening. Typical sensors for an EFI system include the following:

1. Exhaust gas or oxygen sensor
2. Manifold pressure sensor
3. Throttle position sensor
4. Engine temperature sensor
5. Air flow sensor
6. Inlet air temperature sensor
7. Crankshaft position sensor

Since some of these sensors were discussed in the section on computerized carburetor systems, we will only concentrate on the sensors that are particular to the EFI system. These sensors are as follows:

• The THROTTLE POSITION SENSOR is a variable resistor connected to the throttle plate shaft. When the throttle swings open for more power or closes for less power, the sensor changes resistance and signals the computer. The computer can then enrich or lean the mixture as needed

• The AIR FLOW SENSOR is used in many EFI systems to measure the amount of outside air entering the engine. It is usually an air flap or door that operates a variable resistor. Increased air flow opens the air flap more to change the position of the resistor. Information is sent to the computer indicating air inlet volume.

• The INLET AIR TEMPERATURE SENSOR measures the temperature of the air entering the engine. Cold air is more dense, requiring a little more fuel. Warm air is NOT as dense as cold, requiring a little less fuel. The sensor helps the computer compensate for changes in outside air temperature and maintain an almost perfect air-fuel mixture ratio.

• The CRANKSHAFT POSITION SENSOR is used to detect engine speed It allows the computer to change injector openings with changes in engine rpm.

The signal from the engine sensors can be either a digital or an analog type output. Digital signals are on-off signals. An example is the crankshaft position sensor that shows engine rpm. Voltage output or resistance goes from maximum to minimum, like a switch. An analog signal changes in strength to let the computer know about a change in condition. Sensor internal resistance may smoothly increase or decrease with temperature, pressure, or part position. The sensor acts as a variable resistor.

Basic operation of an electronic-timed injection system is as follows:

• Fuel is fed by a high-pressure electric fuel pump to the injectors that are connected in parallel to a common fuel line.

• The fuel pressure regulator is installed in-line with the injectors to keep fuel pressure constant by diverting excess fuel back to the tank.

• Each injector contains a solenoid valve and is normally in a closed position. With a pressurized supply of fuel behind it, each injector will operate individually whenever electric current is applied to the solenoid valve.

• The electronic computer sends the electric impulses and provides the proper amount of fuel. The computer receives a signal for the ignition distributor to establish the timing sequence.

• By sending electric current impulses to the injectors in a sequence timed to coincide with the needs of the engine, the system will supply fuel to the engine as it should.

CONTINUOUS FUEL INJECTION SYSTEM

Continuous fuel injection systems (fig. 4-45) provide a continuous spray of fuel from each injector at a point in the intake port located just before the intake valve. Because the entrance of the fuel into the cylinder is controlled by the intake valve, the continuous system fulfills the requirements of a gasoline engine.

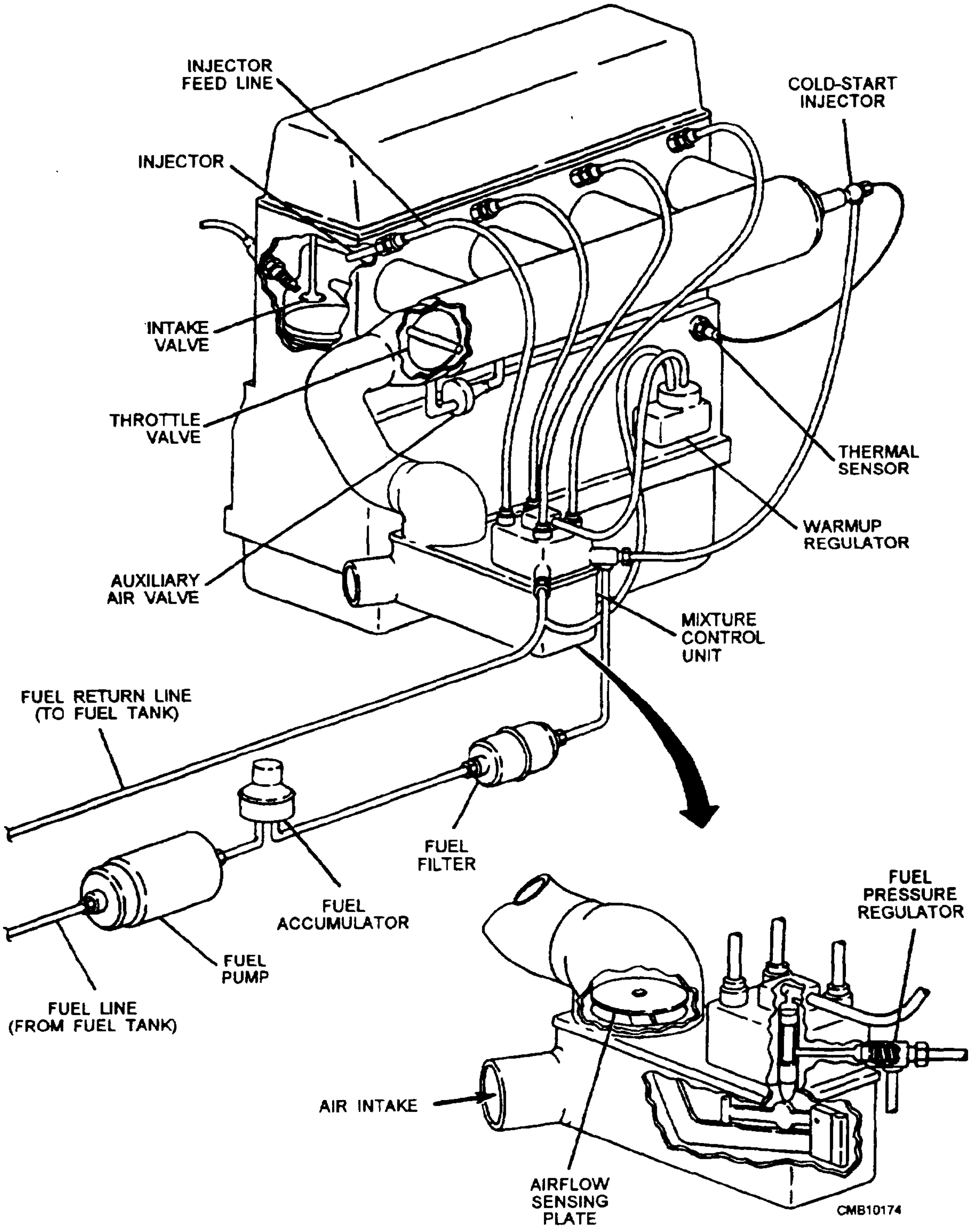

Figure 4-45.—Continuous fuel injection system.

Basic operation of a continuous fuel injection is as follows:

- Fuel is fed to the system by an electric fuel pump that delivers fuel to the mixture control unit. A fuel pressure regulator maintains fuel line pressure and sends excess fuel back to the tank.

- The mixture control unit regulates the amount of fuel that is sent to the injectors based on the amount of air flow through the intake and the engine temperature. The unit is operated by the air flow sensing plate and warm-up regulator.

- The accelerator pedal regulates the rate of air flow through the intake by opening and closing the throttle valve.

- A cold-start injector is installed in the intake to provide a richer mixture during engine start-up and warm-up. It is actuated by electric current from the thermal sensor any time the temperature of the coolant is below a certain level.

The injector for a continuous fuel injection system is a simple spring-loaded valve. It injects fuel all the time the engine is running. A spring holds the valve in a normally closed position with the engine OFF. This action keeps fuel from dripping into the engine. When the engine STARTS, fuel pressure builds and pushes the injector valve open. A steady stream of gasoline then sprays toward each intake valve. The fuel is pulled into the engine when the intake valves open

THROTTLE BODY INJECTION SYSTEM

The throttle body injection (TBI) system (fig. 4-46) uses one or two injector valves mounted in a throttle body assembly. The injectors spray fuel into the top of the throttle body air horn The TBI fuel spray mixes with the air flowing through the air horn. The mixture is then pulled into the engine by intake manifold vacuum. The throttle body injection assembly typically consists of the following: throttle body housing, fuel injectors, fuel pressure regulator, throttle positioner, throttle position sensor, and throttle plates.

- The THROTTLE BODY housing, like a carburetor body, bolts to the pad on the intake manifold. It houses the metal castings that hold the injectors, the fuel pressure regulator, and the throttle plates. The throttle plates are located in the lower section of the body. A linkage or cable connects the throttle plates with the accelerator pedal. An inlet fuel line and outlet return line connects to the fittings on the body.

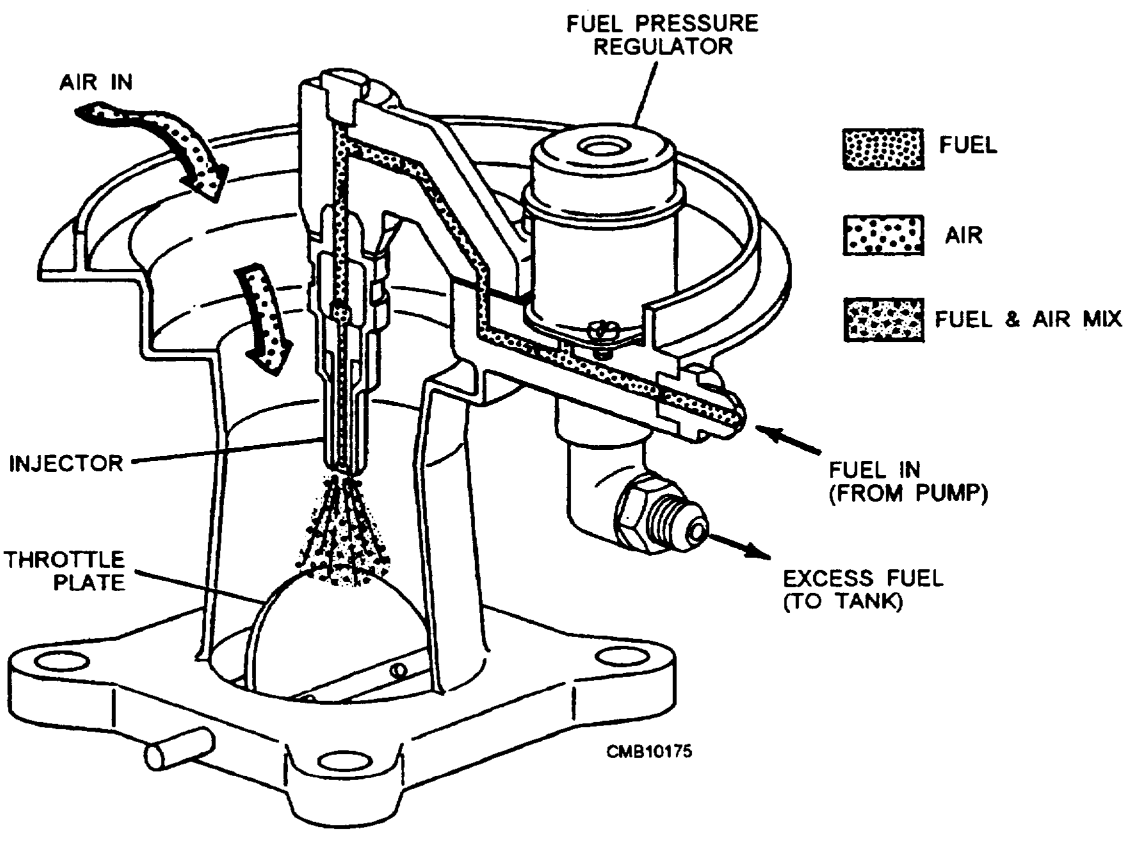

Figure 4-46.—Throttle body injection.

• The THROTTLE BODY INJECTOR consists of an electric solenoid coil, armature or plunger, ball or needle valve and seat, and injector spring. Wires from the computer connect to terminals on the injectors. When the computer energizes the injectors, a magnetic field is produced in the injector coil. The magnetic field pulls the plunger and valve up to open the injector. Fuel can then squirt through the injector nozzle and into the engine.

• The THROTTLE BODY PRESSURE REGULATOR consists of a fuel valve, a diaphragm, and a spring. When fuel pressure is low, the spring holds the fuel valve closed, causing pressure to build as fuel flows into the regulator from the fuel pump. When a preset pressure is reached, pressure acts on the diaphragm. The diaphragm compresses the spring and opens the fuel valve. Fuel can then flow back to the fuel tank, limiting the maximum fuel pressure at the injectors.

• 'The THROTTLE POSITIONER is used on throttle body assemblies to control engine idle speed. The computer actuates the positioner to open or close the throttle plates. In this way, the computer can maintain a precise idle speed with changes in engine temperature, load, and other conditions.

Although throttle body injection does not provide the precise fuel distribution of the direct port injection, it is much cheaper to produce and provide a much higher degree of precision fuel metering than a carburetor.

Q9. What type of fuel injection system is the most precise but is also the most complex?

Q10. In an electronic fuel injection system, what sensor is used to detect engine speed?

Q11. On a throttle body injection system, what device is used to control engine idle speed?

EXHAUST AND EMISSION CONTROL SYSTEMS

LEARNING OBJECTIVE: *Identify components of the exhaust and emission control systems. Describe the operation of the exhaust and emission control systems.*

Over the past several years, exhaust and emission control has greatly increased because of stringent antipollution laws and EPA guidelines. This has made the exhaust and emission control systems of vehicles invaluable and a vital part of today's vehicles.

The waste products of combustion are carried away from the engine to the rear of the vehicle by the exhaust system where they are expelled to the atmosphere. The exhaust system also serves to dampen engine noise. The parts of a typical exhaust system include the following: exhaust manifold, header pipe, catalytic converter, intermediate pipe, muffler, tailpipe, hangers, heat shields, and muffler clamps.

The control of exhaust emissions is a difficult job. The ideal situation would be to have the fuel combine completely with the oxygen from the intake air. The carbon would then combine with the oxygen to form carbon dioxide (CO_2); the hydrogen would combine to form water (H_2O); and the nitrogen present in the intake would stand alone. The only other product present in the exhaust would be oxygen from the intake air that was not used in the burning of the fuel. In a real life situation, however, this is not what happens. The fuel never combines completely with the oxygen, and undesirable exhaust emissions are created as a result.

The most dangerous of the emissions is CARBON MONOXIDE (CO) which is a poisonous gas that is colorless and odorless. CO is formed as a result of insufficient oxygen in the combustion mixture and combustion chamber temperatures that are too low. Other exhaust emissions that are considered major pollutants are as follows:

• HYDROCARBONS (HC) are unburned fuel. They are particulate (solid) in form, and, like carbon monoxide, they are manufactured by insufficient oxygen in the combustion mixture and combustion chamber temperatures that are too low. Hydrocarbons are harmful to all living things. In any urban area where vehicular traffic is heavy, hydrocarbons in heavy concentrations react with the sunlight to produce a brown fog, known as photochemical smog.

• OXIDES OF NITROGEN (NO_X) are formed when nitrogen and oxygen in the intake air combine when subjected to high temperatures of combustion. Oxides of nitrogen are harmful to all living things.

The temperatures of the combustion chamber would have to be raised to a point that would melt pistons and valves to eliminate carbon monoxide and carbon dioxide emissions. This is compounded with the fact that oxides of nitrogen emissions go up with any increase in the combustion chamber temperature. Knowing these facts, it can be seen that emission control devices are necessary.

EXHAUST MANIFOLD

The exhaust manifold (fig. 4-47) connects all the engine cylinders to the exhaust system. It is usually made of cast iron. If the exhaust manifold is properly formed, it can create a scavenging action that will cause all of the cylinders to help each other get rid of exhaust gases. Back pressure (the force that the pistons must exert to push out the exhaust gases) can be reduced by making the manifold with smooth walls and without any sharp bends. All these factors are taken into consideration when the exhaust manifold is designed, and the best possible manifold is manufactured to fit into the confines of the engine compartment.

MANIFOLD HEAT CONTROL VALVE

On some gasoline engines, a valve is placed in the exhaust manifold to deflect exhaust gases toward a hot spot in the intake manifold until the engine reaches operating temperature (fig. 4-48). This valve is a flat metal plate that is the same shape as the opening that controls it. It pivots on a shaft and is operated by a thermostatic coil spring. The spring pulls the valve closed against a counterweight before warm-up. The spring expands as the engine warms up, and the counterweight pulls the valve open.

MUFFLER

The muffler (fig. 4-49) reduces the acoustic pressure of exhaust gases and discharges them to the atmosphere with a minimum of noise. The muffler usually is located at a point about halfway in the vehicle with the exhaust pipe between it and the exhaust manifold and the tailpipe leading from the muffler to the rear of the vehicle.

The inlet and outlet of the muffler usually is slightly larger than their connecting pipes, so that it may hook up by slipping over them. The muffler is then secured to the exhaust pipe and tailpipe by clamps.

A typical muffler has several concentric chambers with openings between them. The gas enters the inner chamber and expands, as it works its way through a series of holes in the other chambers and finally to the atmosphere. They must be designed also to quiet exhaust noise while creating minimum back pressure. High back pressure could cause loss of engine power and economy and also cause overheating.

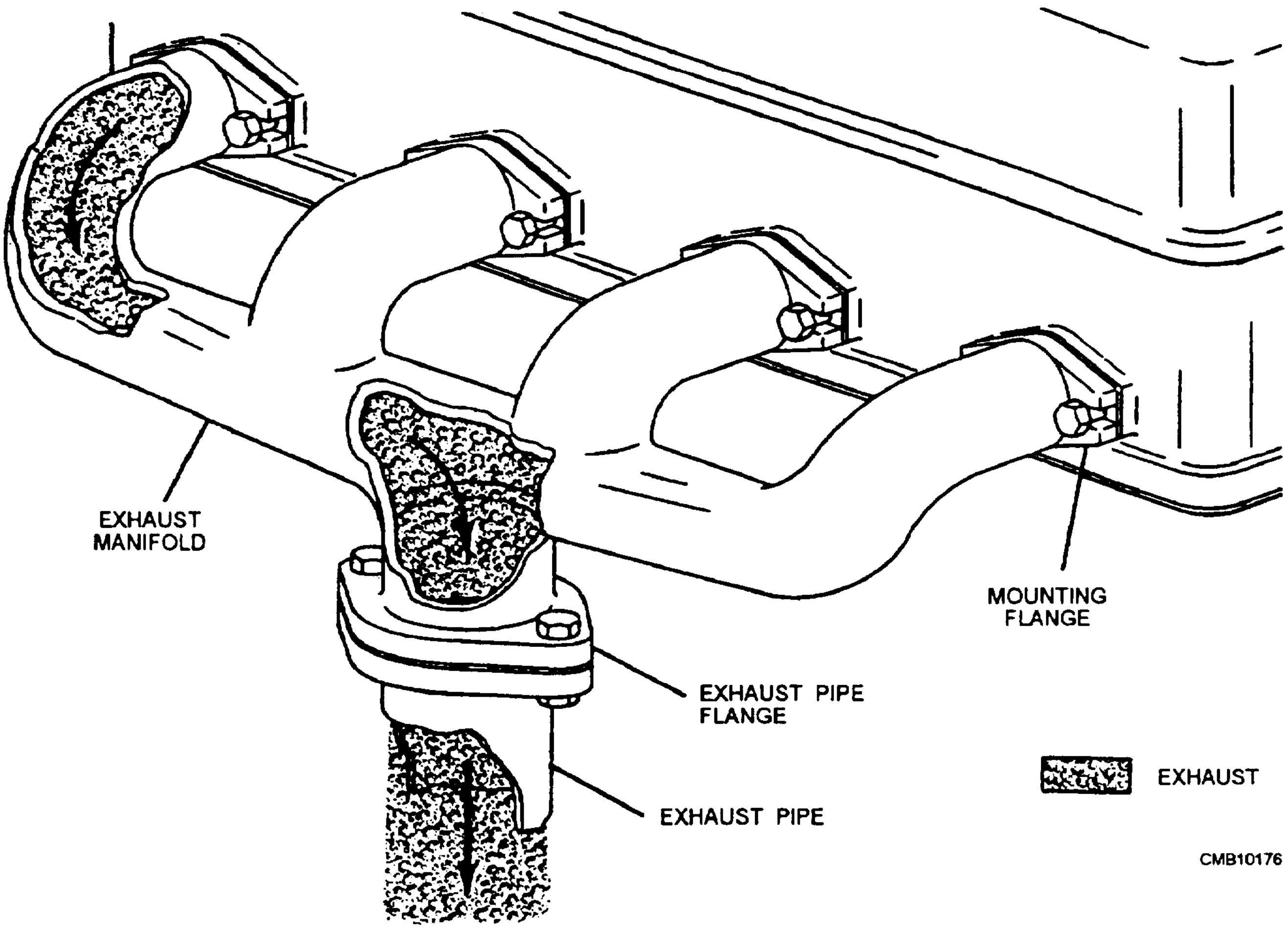

Figure 4-47.—Exhaust manifold.

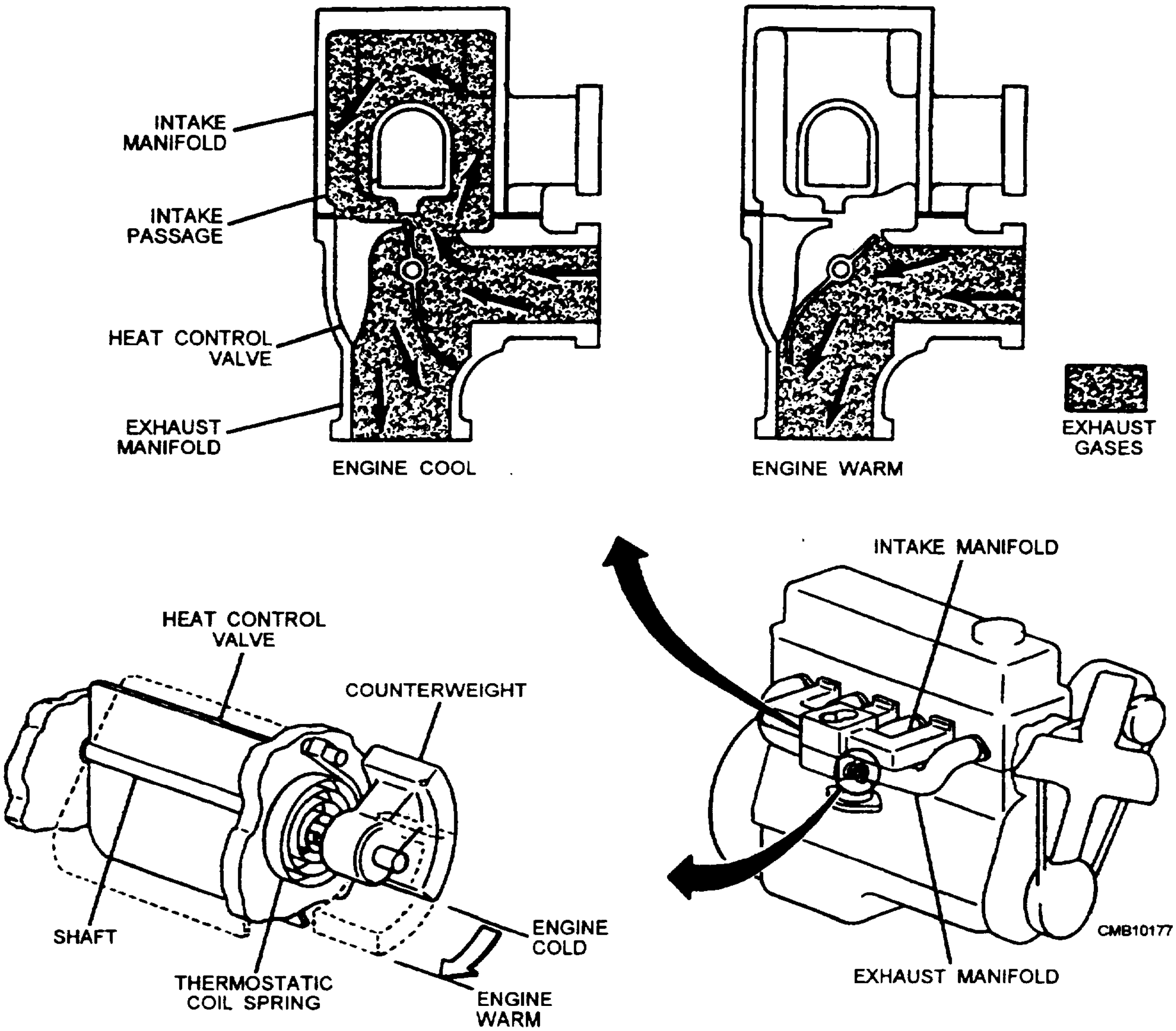

Figure 4-48.—Manifold heat control valve.

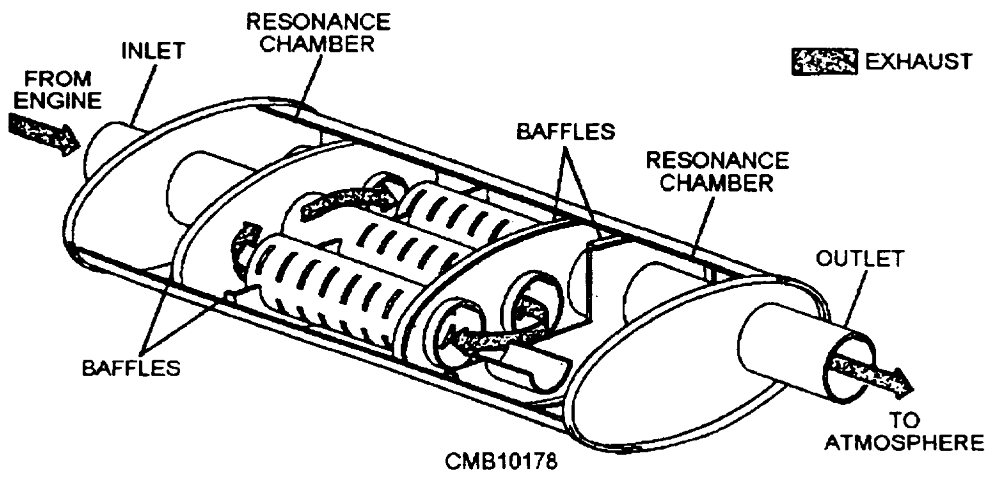

Figure 4-49.—Muffler.

Exhaust system components usually are made of steel. They are coated with aluminum or zinc to retard corrosion. Stainless steel also is used in exhaust systems in limited quantities due to its high cost. A stainless steel exhaust system will last indefinitely.

CATALYTIC CONVERTERS

It is impossible to keep carbon monoxide and hydrocarbon emissions at acceptable levels by controlling them in the cylinder without shortening engine life considerably. The most practical method of controlling these emissions is outside the engine using a catalytic converter. The catalytic converter is similar in appearance to the muffler and is positioned in the exhaust system between the engine and muffler. As the engine exhaust passes through the converter, carbon monoxide and hydrocarbons are oxided (combined with oxygen), changing them into carbon dioxide and water.

The catalytic converter contains a material (usually platinum or palladium) that acts as a catalyst. The catalyst is something that causes a reaction between two substances without actually getting involved. In the case of the catalytic converter, oxygen is joined chemically with carbon monoxide and hydrocarbons in the presence of its catalyst. Because platinum and palladium are both very precious metals and the catalyst must have a tremendous amount of surface area in order to work properly, it has been found that the following internal structures work best for catalytic converters:

- PELLET TYPE (fig. 4-50) is filled with aluminum oxide pellets that have a very thin coating of catalytic material. Aluminum oxide has a rough outer surface, giving each pellet a tremendous amount of surface area. The converter contains baffles to ensure maximum exposure of the exhaust to the pellets.

- MONOLITHIC TYPE (fig. 4-50) uses a one-piece ceramic structure in a honeycomb style form. The structure is coated thinly with a catalytic material. The honeycomb shape has a tremendous surface area to ensure maximum exposure of exhaust gases to the catalyst.

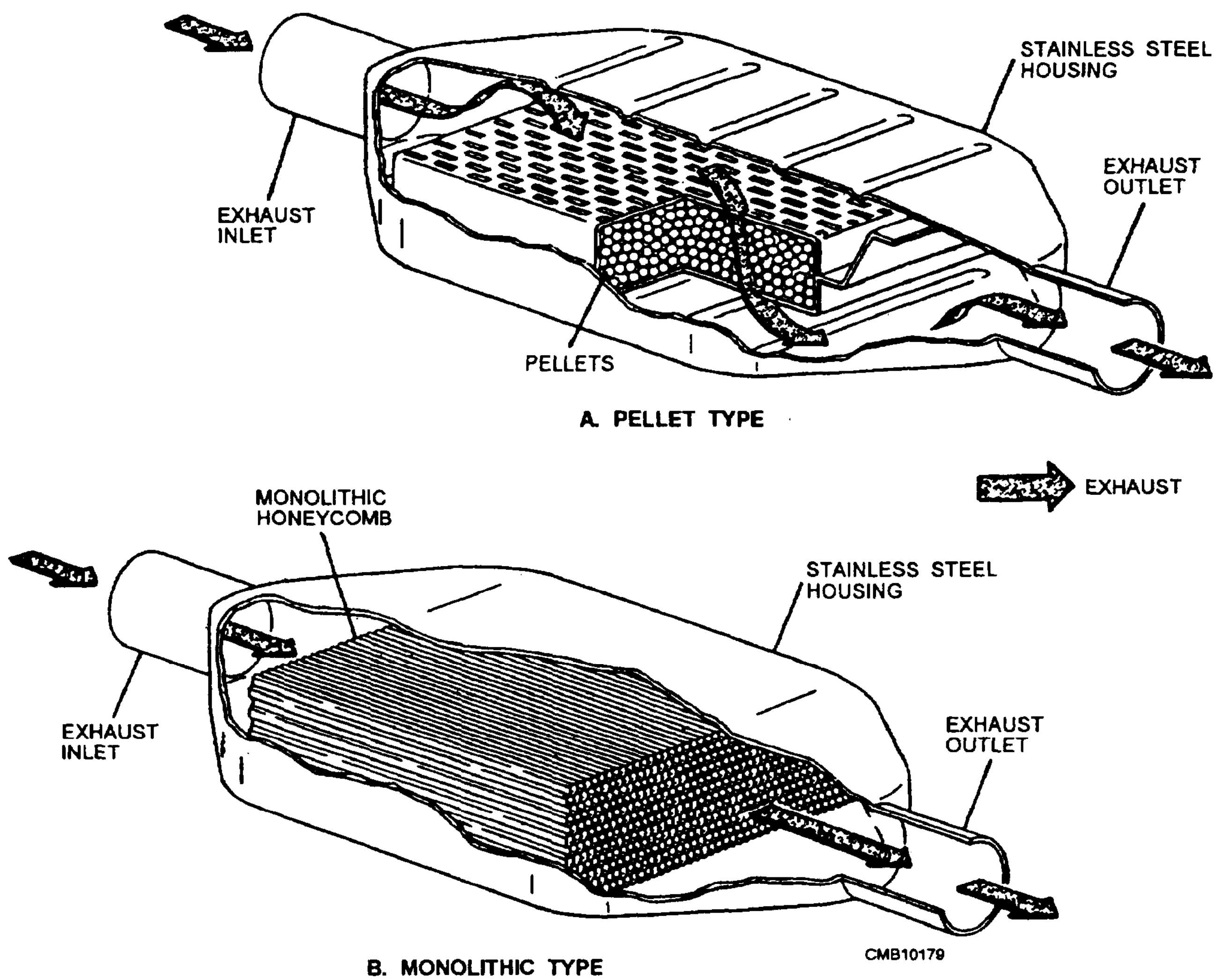

Figure 4-50.—Catalytic converter.

An adequate amount of oxygen must be present in the exhaust system for the catalytic converter to operate; therefore, a supporting system, such as an air injection system, usually is placed on catalytic converter equipped engines to dilute the exhaust stream with fresh air.

AIR INJECTION SYSTEM

An air injection system (fig. 4-51) forces fresh air into the exhaust ports of the engine to reduce HC and CO emissions. The exhaust gases leaving an engine can contain unburned and partially burned fuel. Oxygen from the air injection system causes this fuel to continue to burn. The major parts of the system are the air pump, the diverter valve, the air distribution manifold, and the air check valve.

- The AIR PUMP is belt-driven and forces air at low pressure into the system. A hose is connected to the output of the diverter valve.

- The DIVERTER VALVE keeps air from entering the exhaust system during deceleration. This prevents backfiring in the exhaust system. Also, the diverter valve limits maximum system air pressure when needed, releasing excessive pressure through a silencer or a muffler.

- AIR DISTRIBUTION MANIFOLD directs a stream of fresh air toward each engine exhaust valve. Fittings on the air distribution manifold screw into a threaded hole in the exhaust manifold or cylinder head.

- AIR CHECK VALVE is usually located in the line between the diverter valve and the air distribution manifold. It keeps exhaust gases from entering the air injection system.

Basic operation of the air injection system is as follows:

- When the engine is running, the spinning vanes of the air pump force air into the diverter valve. If not decelerating, the air is forced through the diverter valve, the check valve, the air injection manifold, and into the engine. The fresh air blows on the exhaust valves.

- During periods of deceleration, the diverter valve blocks air flow into the engine exhaust manifold. This prevents a possible backfire that could damage the exhaust system of the vehicle. When needed, the diverter valve will release excess pressure in the system.

POSITIVE CRANKCASE VENTILATION (PCV) SYSTEM

The positive crankcase ventilation system uses manifold vacuum to purge the crankcase blow-by fumes. The fumes are then aspirated back into the engine where they are reburned.

A hose is tapped into the crankcase at a point that is well above the engine oil level. The other end of the hose is tapped into the intake manifold or the base of the carburetor.

NOTE

> If the hose is tapped into the carburetor base, it will be in a location that is between the throttle valves and the intake manifold so that it will receive manifold vacuum.

An inlet breather is installed on the crankcase in a location that is well above the level of the engine oil. The inlet breather also is located strategically to ensure complete purging of the crankcase fresh air. The areas of the crankcase where the vacuum hose and inlet breather are tapped have baffles to keep motor oil from leaving the crankcase.

A flow control valve is installed in the line that connects the crankcase to the manifold. It is called a positive crankcase ventilation (PCV) valve (fig. 4-52) and serves to avoid the air-fuel mixture by doing the following:

- Any periods of large throttle opening will be accompanied by heavy engine loads. Crankcase blow-by will be at its maximum during heavy engine loads. The PCV valve will react to the small amount of manifold vacuum that also is present during heavy engine loading by opening fully through the force of its control valve spring. In this way, the system provides maximum effectiveness during maximum blow-by periods.

- Any period of small throttle opening will be accompanied by small engine loads, high manifold vacuum, and a minimum amount of crankcase blow-by. During these periods, the high manifold vacuum will pull the PCV valve to its position of minimum opening. This is important to prevent an excessively lean air-fuel mixture.

- In the event of engine backfire (flame traveling back through the intake manifold), the reverse pressure will push the rear shoulder of the control valve against

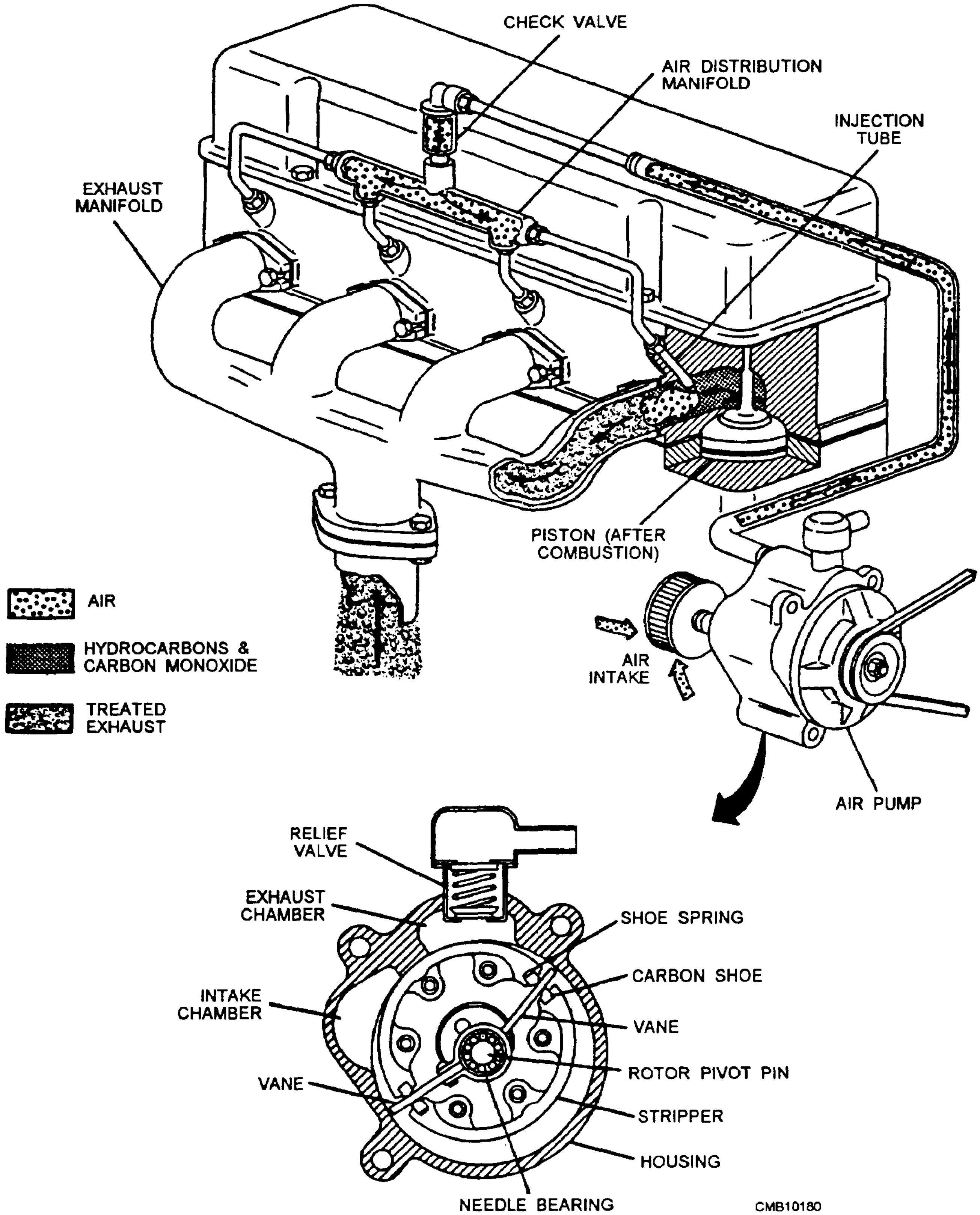

Figure 4-51.—Air injection system.

the valve body. This will seal the crankcase from the backfire which could otherwise cause an explosion.

The positive crankcase ventilation system can be either the open or closed type (fig. 4-52).

- The open type has an inlet breather that is open to the atmosphere. When this system is used, it is possible for a portion of the crankcase blow-by to escape through the breather whenever the engine is under a sustained heavy load.

- The closed type has a sealed breather that is connected to the air filter by a hose. Any blow-by gases that escape from the breather when this system is used will be aspirated into the carburetor and reburned.

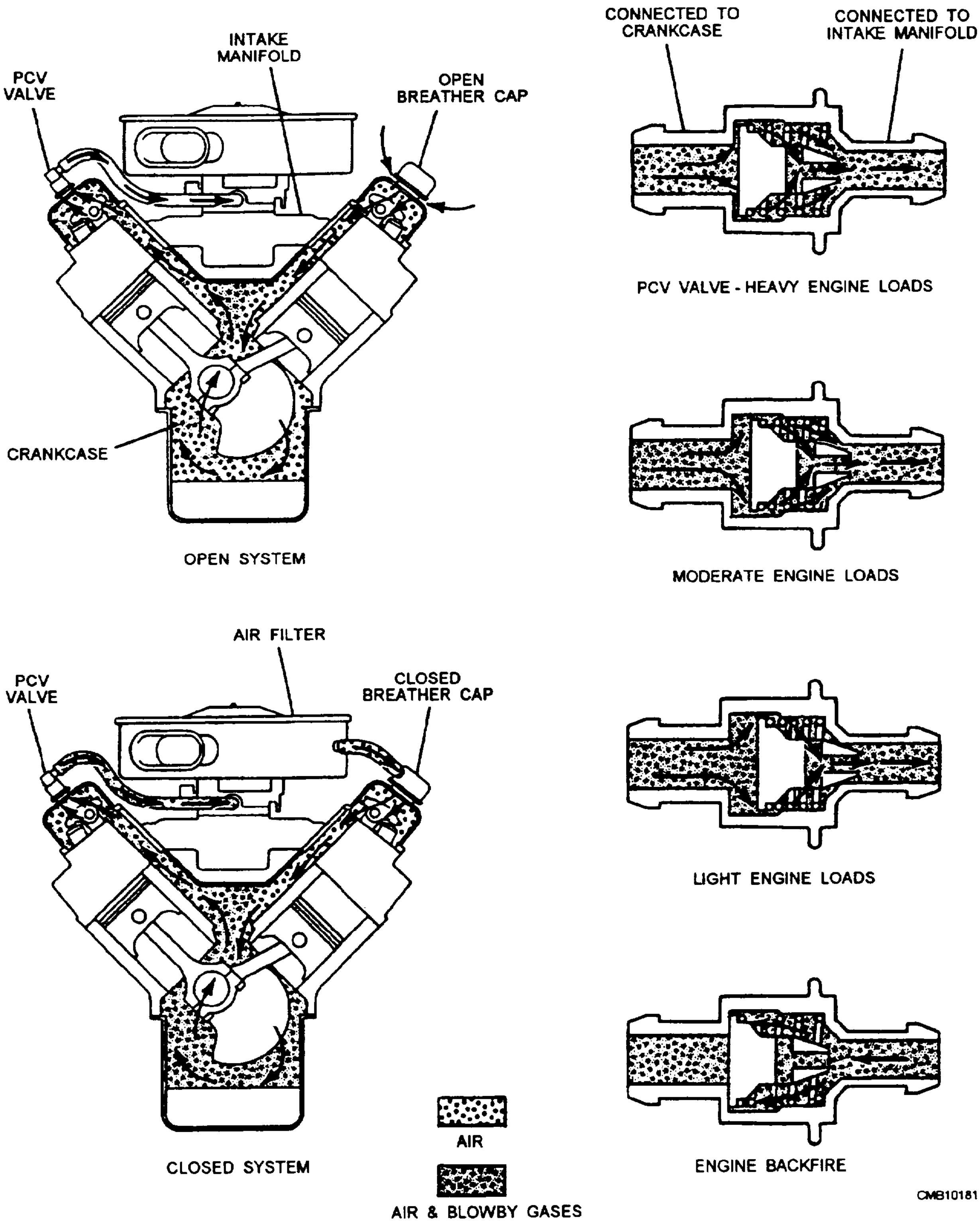

Figure 4-52.—PCV system.

EXHAUST GAS RECIRCULATION (EGR) SYSTEM

When the temperature of the combustion flame exceeds approximately 2,500°F, the nitrogen that is present in the intake air begins to combine with oxygen to produce oxides of nitrogen (NO_x). The exhaust gas recirculation (EGR) system (fig. 4-53) helps to control the formation of oxides of nitrogen by recirculating a portion of the exhaust gases back through the intake manifold, resulting in cooler combustion chamber temperatures.

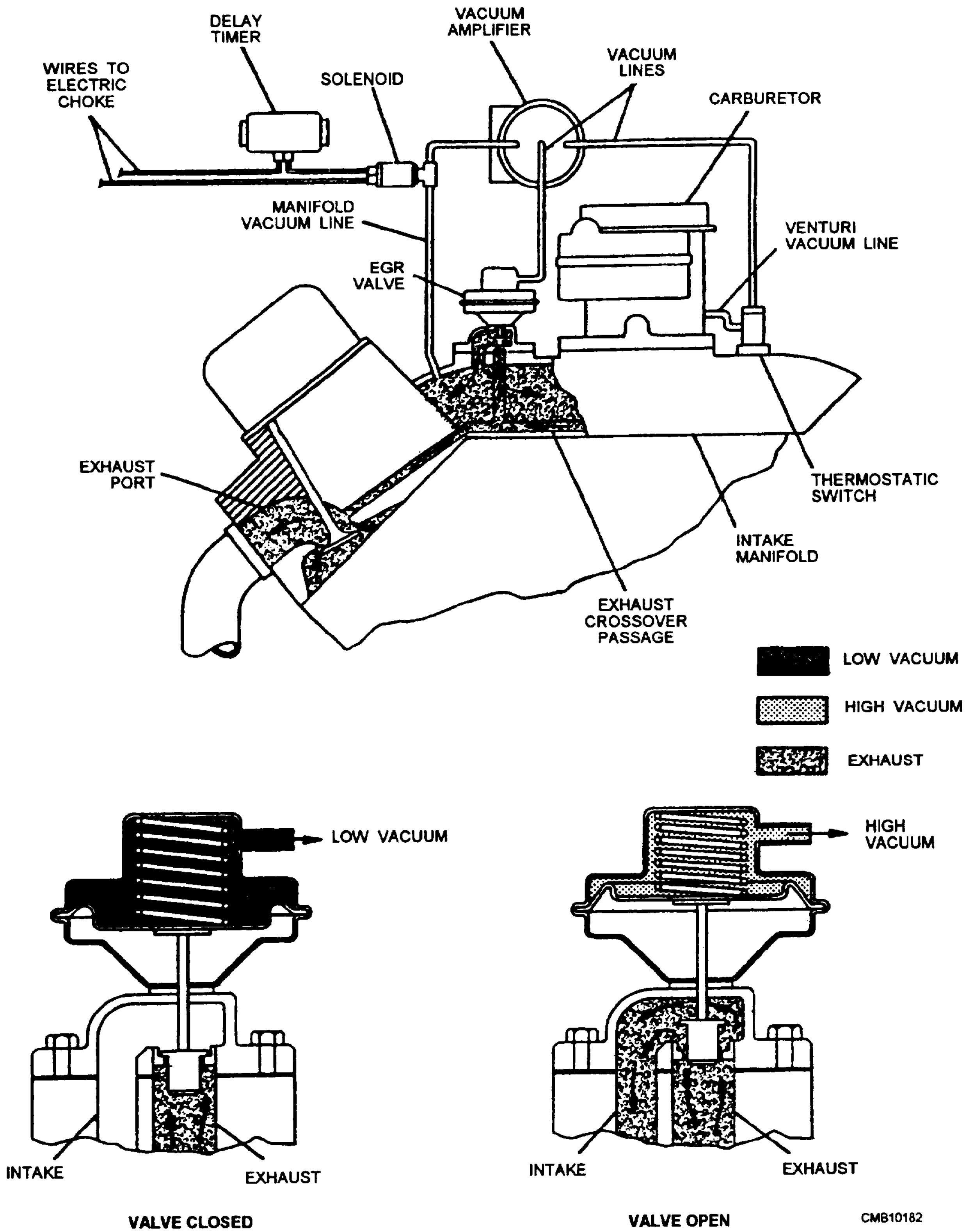

Figure 4-53.—EGR system.

A basic EGR system is simple, consisting of a vacuum operated EGR valve and a vacuum line from the carburetor. The EGR valve usually bolts to the engine intake manifold or a carburetor plate. Exhaust gases are routed through the cylinder head and intake manifold to the EGR valve.

The EGR valve consists of a vacuum diaphragm, a spring, an exhaust gas valve, and a diaphragm housing. It is designed to control exhaust flow into the intake manifold.

Though there are minor differences between systems, the basic operation of an exhaust gas recirculation system is as follows:

- At idle, the throttle plate in the carburetor or fuel injection throttle body is closed. This blocks off engine vacuum, so it cannot act on the EGR valve. The EGR spring holds the valve shut, and the exhaust gases do NOT enter the intake manifold. If the EGR valve were to open at idle, it could upset the air-fuel mixture and the engine would stall.

- When the throttle plate is swung open to increase speed, engine vacuum is applied to the EGR hose. Vacuum pulls the EGR diaphragm up. In turn, the diaphragm pulls the valve open. Engine exhaust can enter the intake manifold and combustion chambers. At higher engine speeds, there is enough air flowing into the engine that the air-fuel mixture is not upset by the open EGR valve.

There are two different methods of supply vacuum to the EGR valve as follows:

- The first method uses a vacuum port into the carburetor throat located just above the throttle plate. As the throttle begins to open, vacuum will begin to be applied to the port and operates the EGR valve. The valve will continue to operate fully until approximately half throttle is reached. As the throttle is open past the halfway point, exhaust gas recirculation gradually will diminish to zero, as the throttle approaches the fully opened position.

- The second method uses a vacuum port that is directly in the carburetor venturi (fig. 4-53). The carburetor venturi provides vacuum for the EGR valve any time the engine is running at high speed. The problem with using venturi vacuum is that it is not strong enough to open the EGR valve. So to make it work, manifold vacuum is used to operate the EGR valve through a vacuum amplifier. The vacuum amplifier switches the manifold vacuum supply to the EGR valve whenever venturi vacuum is applied to its signal port. At times of large engine loading (wide, open throttle), manifold vacuum will be weak, producing the desired condition of no exhaust gas recirculation.

An engine coolant temperature switch may be used to prevent exhaust gas recirculation when the engine is cold. A cold engine does not have extremely high combustion temperatures and does not produce very much NO_x. By blocking vacuum to the EGR valve below 100°F, you can improve the drivability and performance of the cold engine.

FUEL EVAPORIZATION CONTROL SYSTEM

The fuel evaporization control system prevents vapors from the fuel tank and carburetor from entering the atmosphere (fig. 4-54). Older, pre-emission vehicles used vented fuel tank caps. Carburetor bowls were also vented to the atmosphere. This caused a considerable amount of emissions. Modern vehicles commonly use fuel evaporization control systems to prevent this source of pollution. The major components of the fuel evapotization control systems are the sealed fuel tank cap, fuel air dome, liquid-vapor separator, roll-over valve, fuel tank vent line, charcoal canister, carburetor vent line, and the purge line.

- SEALED FUEL TANK CAP is used to keep fuel vapors from entering the atmosphere through the tank filler neck. It may contain pressure and vacuum valves that open in extreme cases of pressure or vacuum. When the fuel expands (from warming), tank pressure forces fuel vapors out a vent line or line at the top of the fuel tank, not out of the cap.

- FUEL AIR DOME is a hump designed into the top of the fuel tank to allow for fuel expansion. The dome normally provides about 10 percent air space to allow for fuel heating and volume increase.

- LIQUID-VAPOR SEPARATOR is frequently used to keep liquid fuel from entering the evaporation control system. It is simply a metal tank located above the main fuel tank. Liquid fuel condenses on the walls of the separator and then flows back into the fuel tank.

- ROLL-OVER VALVE is sometimes used in the vent line from the fuel tank. It keeps liquid fuel from entering the vent line after an accident where the vehicle rolled upside down. The valve contains a metal ball or plunger valve that blocks the vent line when the valve is turned over.

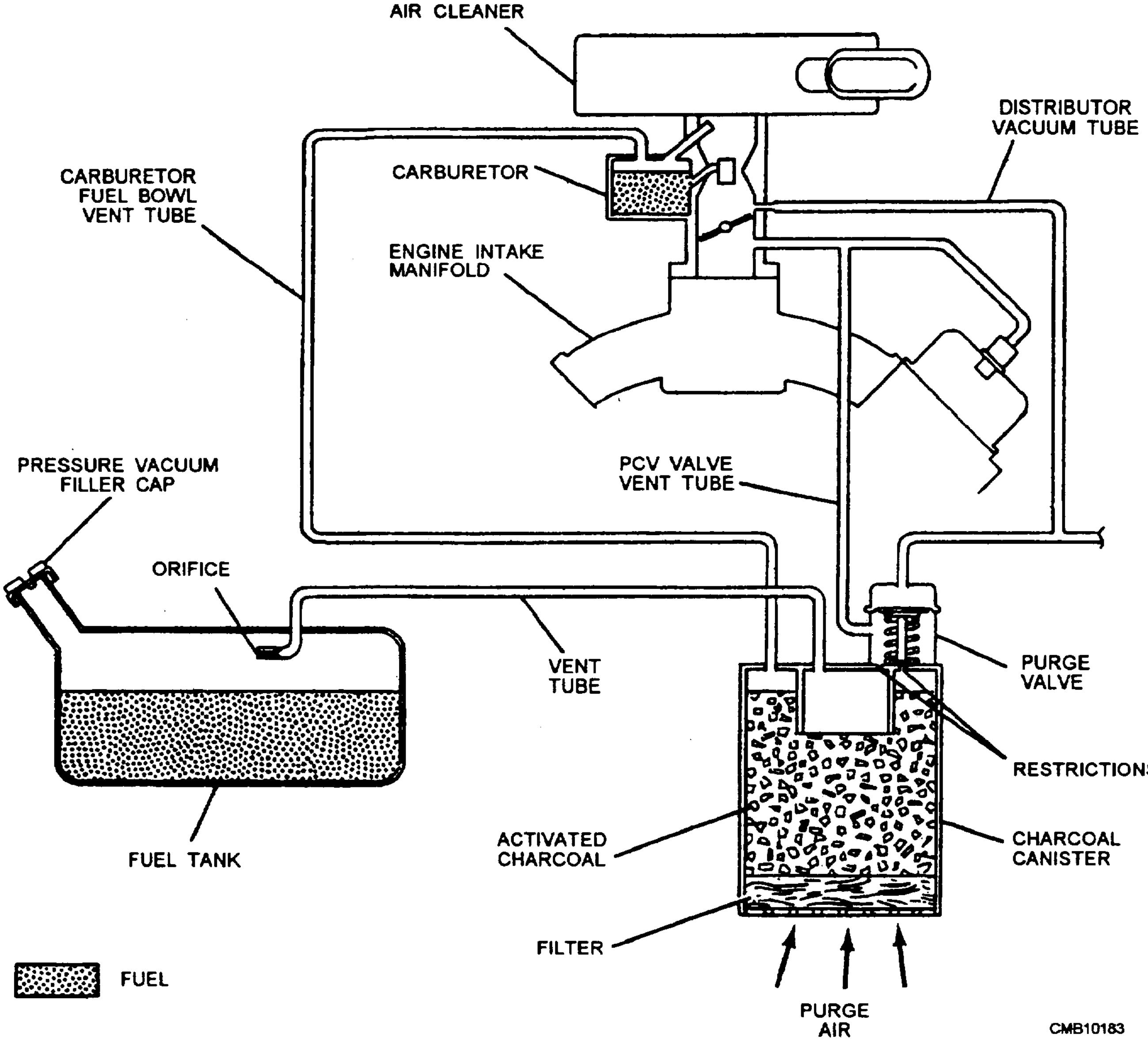

Figure 4-54.—Fuel evaporization system.

- FUELTANK VENTLINE carries fuel vapors up to a charcoal canister in the engine compartment.

- CHARCOAL CANISTER stores fuel vapors when the engine is NOT running. The metal or plastic canister is filled with activated charcoal granules capable of absorbing fuel vapors.

- CARBURETOR VENT LINE connects the carburetor fuel bowl with the charcoal canister. Bowl vapors flow through this line and into the canister.

- PURGE LINE is used for removing or cleaning the stored vapors out of the charcoal canister. It connects the canister and the engine intake manifold.

Basic operation of a fuel evaporization control system is as follows:

- When the engine is running, intake manifold vacuum acts on the purge line, causing fresh air to flow through the filter at the bottom of the canister. The incoming fresh air picks up the stored fuel vapors and carries them through the purge line. The vapors enter the intake manifold and are pulled into the combustion chambers for burning.

- When the engine is shut off, engine heat produces excess vapors. These vapors flow through the carburetor vent line and into the charcoal canister for storage. The vapors that form in the tank flow through the liquid vapor separator into the tank vent line to the charcoal canister. 'The charcoal canister absorbs these fuel vapors and holds them until the engine is started again.

Q12. A gasoline engine produces what three major pollutants?

Q13. What material(s) is used in a catalytic converter to act(s) as a catalyst?

Q14. What type of catalytic converter is of a honeycomb design?

Q15. What device is used to prevent exhaust gas recirculation when the engine is cold?